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Your reference EPOC32 (long)

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Request for grant of a Patent

Form 1/77 **Patents Act 1977**

1 Title of invention

Operating system for a computer based on C++ programming techniques

2. Applicant's details

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4 Reference Number

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An earlier filing date is claimed:

Yes ☐ No ☑

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Filing date

15 (4) (Divisional) ☐ 8(3) ☐ 12(6) ☐ 37(4) ☐

6 Declaration of priority

Country of filing	Priority Application Number	Filing Date

7 Inventorship

The applicant(s) are the sole inventors/joint inventors

Yes ☐ No ☑

8 Checklist

6Ø

	Continuation sheets
Claims 2	Description 12
Abstract	Drawings

Priority Documents

Translations of Priority Documents

Patents Form 7/77

Patents Form 9/77

Patents Form 10/77

Other Attachements: Appendix 1.

9 Request

We request the grant of a patent on the basis of this application

Signed: Origin Date: 13 June 97

(Origin Limited)

Operating System for a Computer Based on C++ Programming Techniques

Field of the Invention

This invention relates to an improved operating system for a computer. In particular, it relates to an operating system which is based on C++ programming techniques. The commercially available embodiment of this operating system is the EPOC32® operating system produced by Psion® Software Plc of England. EPOC32 is a preferred operating system in the mobile computing environment.

Description of the Prior Art

The C++ programming language is widely used for writing application programs for computers, such as Personal Computers, although it has only rarely been widely adopted for writing operating systems. When writing for Personal Computers, there is generally no overriding requirement to either minimise the size of the executable code or to minimise the number of cycles required for executing steps within the program. Typically, performance and ease of authorship are the more significant requirements.

But there are other contexts in which the executable code must occupy the minimum amount of space (e.g. to minimise the amount of ROM and/or RAM required to store it), and to execute in the minimum number of cycles (e.g. to minimise power consumption).

The mobile computing (e.g. personal digital assistants), smart phone (e.g. GSM cellular telephones with in-built word processing, facsimile send/receive and Internet browsing capabilities) and network computer ("NC") environments exemplify contexts in which there are advantages to minimising the code size of the operating system: namely, the hardware costs (particularly ROM and/or RAM) can then be reduced. That is particularly significant in the above contexts since widespread consumer adoption is generally dependent on relatively low hardware pricing. Similarly, minimising processor execution cycles of the operating system is very important in the mobile computing and smart phone contexts, since doing so minimises power consumption and minimising power consumption is critical to long battery life. A fully architected operating system written in C++ would generally be substantial in size and be power hungry. Hence, it would it be unsuitable for the mobile computing, smart phone and NC environments.

Further, it is generally regarded as difficult to design a fully functional operating system in C++ that meets stringent requirements for code size and cycle overhead, particularly the stringent requirements associated with the mobile, smart phone and NC computing environments.

Some Terminology

"Objects of the String Class"

In C++, text (e.g. strings of letters that will actually appear on a computer screen) is represented as an "Object". The implementer skilled in C++ or other object oriented languages will be familiar with this categorisation. Such text related Objects are of a particular type, which we shall call "Objects of the String Class": The kind of Class that an Object belongs to (e.g. in the case of text, the String Class) defines the allowable manipulations that can be performed on that Object. Only certain manipulations can be performed on Objects of the String Class (e.g. concatenating 2 text strings together). A particular Object of the String Class therefore represents a particular text string. It can only be manipulated in certain, well defined ways.

The following steps are performed in conventional C++ programming in order to create an Object of the String Class from an item of text, where the text resides in a file in the filing system:

- set aside a buffer location in memory
- read the text into the buffer using a file reading service
- use a string creation service to turn the buffered data into an Object of the String Class
- discard the buffer contents

The actual storage location of the text string is difficult to identify in C++, but one does not need to know its location since it is the Object of the String Class that one manipulates directly: that in turn causes the actual text string to be manipulated. Hence the Object of the String Class in effect knows the memory location of the text string and can handle all the necessary memory management tasks associated with text manipulation.

Multiple Classes of Objects of the String Class

In the version of C++ known as the draft Standard (ISO Standard ISO/IEC 9899:1990), all Objects of the String Class (as exemplified by the string class in that part of the draft Standard Library of the above Standard referred to as <string>) are handled in a manner that enables sophisticated memory management tasks to be accomplished (e.g. re-allocating buffer space for text that can grow or shrink or be spliced - fully dynamic text). But this level of memory management uses a great deal of code and may require considerable heap space.

Two examples of conventional C++ memory management illustrate this:

Example 1: C++ handling of Literal Text

In C++, there are many instances in which source code contains text strings. These strings are known as 'Literal Text' and are permanently stored in buffer memory on compilation of the source code into executable object code. When Literal Text is to be manipulated, then an Object of the String Class must be created from it. However, creation of that Object of the String Class itself leads to the creation in memory of the text string which the newly created Object of the String Class in fact manipulates. Hence, the text string is duplicated in memory: once in the original buffer that arises on compilation of the source code and again in the memory location associated with the Object of the String Class that enables the text to be manipulated.

As noted above, in some computing environments, code space and power consumption are at a premium. However, in conventional C++ (i.e. as implemented in the draft Standard ISO/IEC 9899:1990), there is no mechanism to overcome the inherent duplication in memory of Literal Text. That is problematic, especially for an operating system since, in an operating system, there are many occasions in which Literal Text must be handled.

Example 2: C++ handling of length limited text

In C++, a programmer handles text using heap memory. Text whose length is limited does not in fact require the fully flexible approach that is needed to handle text whose length is not limited. However, in conventional C++, there is no mechanism for using anything other than fully flexible, fully featured Objects of the String Class,) irrespective of the length of text. That leads to a high overhead in memory management code since handling heap memory is code and cycle intensive.

Overall, text memory management in C++ is code and cycle intensive. Since code space and power consumption are at a premium in mobile environments, the conventional C++ approach would lead to an operating system that is unacceptably large in terms of code size and is also too power hungry.

Statement of the Invention

The operating system of the present invention re-defines Objects of the String Class (i.e. as defined in the draft Standard ISO/IEC 9899:1990), by substituting them with a three fold structure of Objects of the String Class, namely three new Classes of Objects. The conventional, fully featured memory management functionality associated with <string> from the draft Standard ISO/IEC 9899:1990 is not applied to all three of the new classes. Whilst that full functionality is useful in many environments, it is problematic in (inter alia) mobile computing environments in which code space and power consumption are at a premium.

Hence, the generalisation of the inventive concept of the present invention is to minimise code size and cycle overhead by providing, in a computer operating system, a family of three different Classes for handling text strings: each different class is appropriate for a different circumstance. This allows flexibility: for example, the fully featured memory management functionality can now be applied solely to those text strings that actually require it.

We shall refer to this new family of String Class Objects as "Descriptors". In a preferred embodiment, we call the members of this family "Pointer Descriptors", "Buffer Descriptors" and "Heap Descriptors". Care should be taken to note that these concepts are different (although related to) the established concepts of "pointers", "buffers" and "heaps", with which the skilled implementer will be familiar.

Further, Descriptors are preferably polymorphic: hence, a single service can operate on all Descriptors. That leads to significant savings in code and, to a lesser extent, cycle overhead, since otherwise modified services would be needed for each of different Descriptors.

Hence, in accordance with a first aspect of the present invention, there is provided a computer programmed with an object oriented operating system, in which the operating system is adapted to handle objects related to text strings;

characterised in that the operating system handles all such objects as belonging to one of three classes (namely the Pointer Descriptor Class, the Buffer Descriptor Class and the Heap Descriptor Class), in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

The invention is founded upon the insight that in order to deliver significant reductions in code and cycle overhead, one has to re-design the operating system by substituting the conventional, single form of Object of the String Class (for example) with three different forms of that Object: each form is optimised for different circumstances.

In a preferred form of the invention, conventional, memory intensive text handling techniques are applied only to Objects which fall within the new Descriptor Class which defines Objects requiring such techniques (i.e. Heap Descriptors). The Pointer and Buffer Descriptor Classes are however designed in a manner that reduces code and processor cycles compared to conventional String Classes.

Using the two examples mentioned in the Description of the Prior Art above (i.e. Example 1: C++ handling of literal text and Example 2: C++ handling of length limited text), the operating system of the present invention (i) handles Literal Text in a manner that eliminates the need for a duplicate copy of Literal Text and (ii) handles text which is determined dynamically at run time in a manner that only requires code intensive utilisation of heap memory in those limited circumstances in which it is actually necessary to do so: in other circumstances (for example, where the programmer knows in advance the maximum length of the text), then static memory is used instead. Fuller details of the specific handling is given below (see section titled Detailed Description).

Preferably, the operating system is adapted to handle not only text but also raw data using the same three fold structure.

In addition to the combined computer/operating system as defined above, one can identify further inventive aspects. For example, any device that has to interface with such an operating system must also use the same three-fold structure for Objects of the String Class. For example, driver software for peripherals such as solid state memory devices will have to use this three fold-structure. Likewise, control panel software for peripherals will also have to.

Hence, in a second aspect of the present invention, there is provided a peripheral device for a computer programmed with an object oriented operating system, in which the operating system is adapted to handle objects related to text strings;
characterised in that the operating system handles all such objects as belonging to one of three classes (namely the Pointer Descriptor Class, the Buffer Descriptor Class and the Heap Descriptor Class), in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead and is further characterised in that the peripheral device is programmed to handle objects which also fall into the above three classes.

In a third aspect of the present invention, there is provided an operating system encoded on computer readable media, in which the operating system handles objects related to text strings; characterised in that the operating system is adapted to handle all such objects as belonging to one of three classes (namely the Pointer Descriptor Class, the Buffer Descriptor Class and the Heap Descriptor Class), in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

In a fourth aspect of the invention, there is provided a method of operating a micro-processor using an operating system, in which the operating system is adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes (namely the Pointer Descriptor Class, the Buffer Descriptor Class and the Heap Descriptor Class), in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

In a fifth aspect, there is provided computer readable media encoded with an operating system adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes, in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead. Typically, the computer readable media will be a masked ROM. For distribution purposes, the media may also be a conventional CD-ROM or floppy disc.

Detailed Description

The present invention will be described in relation to an embodiment known as EPOC32. EPOC32 is a 32 bit operating system developed by Psion Software plc of England for use in (inter alia) mobile and smart phone environments. Further details of the EPOC32 embodiment are disclosed in the SDK on EPOC32 published by Psion Software Plc, England, a section of which is attached as Appendix 1. Reference may also be made to the white paper on EPOC32, also published by Psion Software Plc, England, a section of which is attached as Appendix 2. To the extent possible without limiting in any way the rights of the inventors and assignees of this invention, the full SDK is incorporated by reference into this specification.

EPOC32 has been ported to run on a number of different micro-processor architectures. The details of porting an operating system per se are beyond the scope of this specification, but will be understood by those skilled in the arts. In particular, EPOC32 has been ported to run on ARM RISC-based micro-processors from Advanced RISC Machines of England. Various models of ARM micro-processors are widely used in digital cellular telephones and will be familiar to those skilled in the art. However, the invention can be realised on many different micro-processors. Hence, the claims of this specification should be read to cover any and every hardware and software implementation in which the operating system performs the functions as limited in the claims.

Returning to the examples of Literal Text and Length Limited Text given in the Prior Art discussion above, EPOC32 applies the above three-fold structure for Objects of the String Class as follows:

Example 1: Literal Text in EPOC32

As explained above, in conventional C++, a text string relating to Literal Text is duplicated in memory: once in the original buffer that arises on compilation of the source code and again in the memory location associated with the Object of the String Class that enables the text to be manipulated. That duplication is wasteful.

EPOC32 however uses a Pointer Descriptor which points to the original memory location of the Literal Text (i.e. as laid down by the compiler). This Pointer Descriptor (called the TPtrC Pointer Descriptor in EPOC32) is the Object of the String Class for Literal Text. (In C++,

pointers are not usually regarded as Objects per se). Hence, the hybrid pointer/object in EPOC32 leads to the complete elimination of the need for an additional copy of Literal Text.

Example 2: Length Limited Text in EPOC32

As noted above, in conventional C++, there is no mechanism for using anything other than fully flexible, fully featured Objects of the String Class,) irrespective of the length of text. That leads to a high overhead in memory management code since handling heap memory is code and cycle intensive.

In EPOC32, there is a particular class of String Objects, known as Buffer Descriptors, which are size limited. Because they are size limited, complex memory allocation code is not required to manipulate them. Further, Buffer Descriptors can use Static Memory (rather than heap memory). Static memory cannot be re-allocated in the code intensive fashion that heap memory can be, but is more efficient to use in that fewer code cycles are required to achieve the necessary manipulations (hence leading to power saving). Only in the truly dynamic case does EPOC32 require use of the heap memory with its attendant high cycle overhead: Then, the Heap Descriptor Class is used.

EPOC32 lays down the parameters of length limited String Classes using a template class, the 'TBuf' class. (Class templates define the properties of numerous Objects of the String Class; e.g. TBuf is the template for all Buffer Descriptors - i.e. all Objects of the String Class of the Buffer variant. TBuf defines certain common properties for all such Objects of the String Class.)

EPOC32 exhibits several other significant features which lead to minimising code size and cycle overhead, namely that:

- String and Raw Data Buffer Class Objects act as 'flat' structures
- Descriptors give polymorphic characteristics
- Descriptors allow for UNICODE and ASCII invariant coding

String and Raw Data Buffer Class Objects as flat structures

All Descriptors are 'flat' structures (i.e. if a Descriptor has to be copied, then only the Descriptor itself is copied. In conventional C++, copying an Object requires copying not only of the Object itself, but also all related pointers and the data pointed to - i.e. the complex, related structure that gives an Object meaning.) In EPOC32, copying a Descriptor is therefore

far more economic in memory overhead and cycles than copying an equivalent Object in ordinary C++.

This is achieved in EPOC32 as follows, for Buffers and Pointers:

Buffer Descriptors (TBuf) contain the actual text referenced by the Buffer: hence, copying the Buffer inherently copies the related text. There is no need to copy a pointer and related data as there would be in C++.

Pointer Descriptors (TPtr) contain a C++ type pointer within them, so that copying TPtr alone is all that is required when duplicating: in conventional C++, one would have had to copy not just one entity, but also related and separate pointers and text.

Descriptors as Polymorphic Objects

A group of Objects are said to exhibit polymorphism if all the Objects in the Group behave like a single Object, yet achieve common behaviour through different mechanisms. Polymorphism is provided for in conventional C++ through Virtual Functions: all Objects which are polymorphic to one another include, at a common location, a pointer to a Virtual Function Table (a pointer is therefore required in each Object). This Table identifies the actual code for each polymorphic function. A separate Table is needed for each class that shares polymorphism. But this approach uses a considerable amount of space, since each pointer is 32 bits (i.e. 4 characters) and each Object needs a pointer to a Virtual Function Table. In addition, a 32 bit length field is also used in each Object.

In (inter alia) mobile operating system environments, this overhead is problematic. EPOC32 addresses this as follows for Objects of the String Class: a 32 bit length field is sub-divided so that the first 4 bits code for the type of Descriptor. A function then looks at the 4 bits and points to the correct text location (e.g. within the Descriptor itself if the Descriptor is a Buffer etc.) Hence, polymorphism is provided for in that each of the three different classes of Descriptors for Objects of the String Class (i.e. Pointer Descriptors, Buffer Descriptors and Heap Descriptors) can be coded for using merely the first 4 bits of a single 32 bit field. Hence, considerable memory savings can be achieved. In more general terms, the field shares a machine word with another data item.

UNICODE and ASCII Invariant Code

In C++, coding for 16 bit Unicode leads to doubling in size of all text data that would otherwise be in 8 bit code. Also, conventionally, a programmer has to decide when writing source code whether to code for text using ASCII or Unicode.

In EPOC32, the same source code is used irrespective of the ultimate choice of ASCII or Unicode. This is achieved by building the system using aliases for Class Names, which are ASCII and Unicode invariant, rather than Classes per se (e.g. Pointer Descriptors, Buffer Descriptors and Heap Descriptors). Hence, instead of building using the Pointer TPtr16 to code for Unicode or TPtr8 to code for ASCII, one instead builds using the TPtr Class Name. At build time, the Class Names can be compiled as either 16bit Unicode or 8bit ASCII. This approach can be used to encompass all character sets which can be encoded in different bit lengths.

Additional Advantages of EPOC32

In C++. text strings are conventionally terminated with a '0' so that the system can readily know where a text string ends. In EPOC32, that is no longer necessary; Descriptors include a statement defining the length of the data referenced. Hence, there is a yet further saving in code since it no longer needs to use '0' terminators to flag the end of each and every text item.

Summary of Descriptors Features

- Descriptors come in 3 classes: **Pointer Descriptors, Buffer Descriptors and Heap Descriptors.**
    - **Pointer Descriptors** come in two forms: constant Pointer Descriptors: TPtrC and modifiable Pointer Descriptors: TPtr
        - constant Pointer Descriptors: TPtrC.
            - Data cannot be modified through this.
            - All member functions are constant.
            - Is used to reference constant strings or data (e.g. data that must not be altered).

        - Is derived from TDesC and hence has a large number of member functions.
    - modifiable Pointer Descriptors: TPtr.
        - Data can be modified though this Descriptor, so long as the data does not extend beyond the maximum length set by the constructor.
        - Points directly to a memory area containing the area to be modified.
        - Pointer length determines number of data items that are contained.
        - Inherits all the TDesC member functions, plus TDes member functions for manipulating and changing data.
    - Pointer Descriptors are separate from the data represented; but are constructed from a pre-existing area in memory..
- **Buffer Descriptors** come in two forms
    - constant Buffer Descriptor, TBufC<TInt S>
        - data can be set into the Descriptor at construction time or by the assignment operator (operator =) later on.
        - length is defined by an integer template: TBufC<40> contains 40 data items.
        - Inherits all the TDesC member functions
    - a modifiable Buffer Descriptor:, TBuf<TInt S>
        - contains data that can be modified, so long as the data is not modified to extend beyond the maximum length.
        - maximum length defines the max. number of data items
        - actual length defines actual number of data items
        - length is defined by an integer template: TBuf<40> contains 40 data items and no more.
        - the data area is part of the Descriptor object
        - useful for containing data which needs to be manipulated and changed , but whose length will not exceed a known maximum (e.g. WP text).
        - Inherits all the TDesC member functions, plus TDes member functions for manipulating and changing data.

- **Heap Descriptors** come in one form only

- constant Heap Descriptor HBufC
- contains a length followed by data
- the data area is part of the Descriptor object; the whole object occupies a cell allocated from the heap.
- Data can be set into the Descriptor at construction time or by the assignment operator (operator =) later on.
- Inherits all the TDesC member functions
- can be re-allocated: data area can expand or contract

Claims

A computing device programmed with an object oriented operating system, in which the operating system is adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

1. A peripheral device for a computer programmed with an object oriented operating system, in which the operating system is adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead and further characterised in that the peripheral device is programmed to handle objects which also fall into the above three classes.

2. An operating system for a computer, in which the operating system is adapted to handle objects related to text strings and is encoded on computer readable media; characterised in that the operating system handles all such objects as belonging to one of three classes in which each class is optimised to perform a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

3. A method of operating a micro-processor using an operating system, in which the operating system is adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes, in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

4. Computer readable media encoded with an operating system adapted to handle objects related to text strings; characterised in that the operating system handles all such objects as belonging to one of three classes, in which each class performs a different function and at least one such class is modified to do so in a way that reduces code and cycle overhead.

5. A product or process as claimed above in which objects in one of the three classes are also pointers.

6. A product or process as claimed in claim 6 in which a pointer points to the original memory location of literal text.

7. A product or process as claimed in Claim 6 in which such an object is a flat structure.

8. A product or process as claimed above in which objects in one of the three classes (other than objects to which claims 6 - 8 relate) handle length limited text.

9. A product or process as claimed in claim 9 in which those objects handling length limited text are serviced by a limited sub-set of the potentially available memory management functions.

10. A product or process as claimed in claim 10 in which those objects handling length limited text use static memory.

11. A product or process as claimed in claim 9 in which those objects handling length limited text are flat structures.

12. A product or process as claimed above in which objects in one of the three classes (other than objects to which claims 6 - 12 relate) use heap memory and require the full set of available memory management functions.

13. A product or process as claimed in any of Claims 1 - 13 above in which objects in any of the three classes are polymorphic.

14. A product or process as claimed in claim 14 in which polymorphism is achieved in one instance by virtue of the operating system including a function that looks to a predetermined field within each object and, depending on the value in that field, leads to a different kind of behaviour.

15. A product or process as claimed in claim 15 above in which the field shares a machine word with another data item.

16. A product or process as claimed in any of Claims 1 - 16 above which is written in 8 bit character set and 16 bit character set invariant form by using aliases for class names that are 8 bit character set and 16 bit character set invariant.

17. A product or process as claimed in any of Claims 17 above which is written in ASCII and Unicode invariant form by using aliases for class names that are ASCII and Unicode invariant.

18. A product or process as claimed in any of Claims 1 - 18 above in which objects in any of the three classes are inherently length specified and hence have no '0' terminator.

Appendix 1: Psion Software Plc "Descriptors" SDK

Overview

E32.descriptors.overview

The descriptor classes offer a safe and consistent mechanism for accessing and manipulating both strings and general binary data regardless of the type of memory that they live in. For example, a string within a code segment in ROM can be handled in a similar way to a file record in RAM.

The data represented by descriptors resides in a data area which is a defined location in memory. This data area is *not expandable*. Operations on descriptor data are safe in the sense that accidental or deliberate attempts to access memory outside the defined data area, are not permitted (In general, code which makes an invalid access, causes an exception (commonly known as a panic).

Descriptors make no distinction between the type of data represented; both strings and binary data are treated in the same way. Although some member functions of a descriptor object are designed to operate on text data, they will, nevertheless, work on binary data. This unifies the handling of both text and binary data and increases efficiency by allowing code to be shared.

Descriptor classes satisfy a number of important requirements:

- They provide support for both UNICODE and ASCII text. The _UNICODE macro is used to select the ASCII or UNICODE build variant.
- They unify the handling of both strings and binary data.
- They allow text or data in ROM to be safely and conveniently referenced.
- They supply rich member functions to manipulate the associated text or data.
- They allow the data to be modified but prevent any attempt to write outside the defined data area.
- They avoid the memory overhead associated with virtual functions.
- They behave as built-in types and can be safely created on the stack and can also be safely *orphaned.*
- (HBufC is allocated on the heap and is an exception to the rule).

ASCII and UNICODE text

E32.descriptors.char-set

ASCII text characters can be represented by 8 bits (one byte) while UNICODE characters require 16 bits (two bytes).

To support both ASCII and UNICODE text, the descriptor classes come in two variants: 8 bit and 16 bit. For example, the descriptor classes: TPtr8 and TPtr16.

Programs can be built to support either UNICODE or ASCII text by using class names which are independent of the build variant. For example, by using the descriptor class TPtr, a system can be built that will use either the TPtr8 or TPtr16 classes. The decision is taken at build time and depends on whether the _UNICODE macro has been defined.

The following code fragments extracted from the E3232def.h header file show how this is implemented by defining the variant independent class names as appropriate.

```
#if defined(_UNICODE)
...
typedef TPtr16 TPtr;
...
#else
...
typedef TPtr8 TPtr;
...
#endif
```

Application code should avoid using 'C' style string literals directly. Use the _S macro to create a 'C' style string of the appropriate width, returning a pointer of the appropriate type. Use the _L macro (_L for "literal") to create a descriptor of the appropriate type. See e32.macro._S and e32.macro._L for the definitions of these macros.
For example,

    const TText* str = _S("Hello");

generates a string of single byte characters in an ASCII build but a string of double-byte characters in a UNICODE build.

    _L("Hello");

generates an 8 bit descriptor in an ASCII build and a 16 bit descriptor in a UNICODE build. Always use _L("abcdef") , for example, rather than plain "abcdef" as it will always construct a descriptor of the correct variant.
Note that an 8 bit 'C' style string and an 8 bit pointer descriptor can be explicitly constructed, independently of the build variant, by using the _S8 and _L8 macros respectively. The corresponding 16 bit versions, _S16 and _L16 are also available.
See e32.macro._S8, e32.macro._L8, e32.macro._S16 and e32.macro._L16 for their definitions.

Length and size

E3232.descriptors.length-and-size

A descriptor characterizes the data it represents by the length of that data. The *length* of a descriptor is the number of data items.
For the 8 bit variants, the length of the descriptor is the number of single-bytes of data it represents; for the 16 bit variants, the length of the descriptor is the number of double-bytes of data it represents.
The *size* of a descriptor is the number of bytes occupied by the descriptor's data; this is not necessarily the same as the descriptor's length. For the 8 bit variants, the size *is* the same as the length but for the 16 bit variants, the size is *twice* the length.
Those descriptors which allow their data to be modified are also characterized by their maximum length. For these descriptors, the length of data represented can vary from zero up to and including this maximum value.
The maximum length for any descriptor is 2^{28}.

Text and binary data

E3232.descriptors.text-and-binary

In 'C', strings are characterized by the need for a zero terminator to flag the end of the string. They suffer from a number of problems. In particular, they cannot include binary data within them (in case that data includes binary zeroes) and operations on them are, in general, inefficient. 'C' strings need to be handled in a different way to binary data, as reflected in the memxxx() and strxxx() function groups in the ANSI 'C' library.
Descriptors allow strings and binary data to be represented in the same way; this allows the same functions to be used in both cases.
For binary data, the 8 bit descriptors should be used explicitly. The distinction between UNICODE and ASCII has no meaning for binary data
Note that there is no practical use for explicit 16 bit binary data.

Memory allocation

E3232.descriptors.alloc

The descriptor classes (except HBufC) behave as built-in types. They allocate no memory and have no destructors. This means that they can be *orphaned* on the stack in the same way as a built-in type. This is particularly important in situations where code can leave. (See E3232.exception.trap.cleanup.requirements for the implications of *orphaning*).
An HBufC descriptor object is allocated on the heap and cannot be created on the stack.

Exceptions

E3232.descriptors.exceptions

All parameters to descriptor member functions are checked to ensure that the operations are correctly specified and that no data is written outside the descriptor's data area.

A particular consequence is that no member function can extend a modifiable descriptor beyond its maximum allocated length.

It is the programmer's responsibility to ensure that all descriptors are sufficiently large to contain their data, either by making the original allocation large enough or by anticipating the need for a larger descriptor and dynamically allocating one at run-time.

The static approach is simpler to implement but if this were to prove wasteful in a specific case, then the dynamic approach could be more worthwhile.

In the event of an exception, it can be safely assumed that no illegal access of memory has taken place and that no data has been moved or damaged.

The descriptor types

E3232.descriptors.types

There are three kinds of descriptor object:

- *pointer* descriptors.
  The descriptor object is separate from the data it represents but is constructed for a pre-existing area in memory. They come in two forms:
  a constant pointer descriptor, TPtrC
  a modifiable pointer descriptor, TPtr
- *buffer* descriptors.
  The data area is part of the descriptor object. They come in two forms:
  a constant buffer descriptor, TBufC<TInt S>
  a modifiable buffer descriptor, TBuf<TInt S>
- *heap* descriptor.
  The data area is part of the descriptor object and the whole object occupies a cell allocated from the heap. This comes in only one form:
  a constant heap descriptor, HBufC

Pointer descriptor - TPtrC

E3232.descriptors.buffer-descriptor.TPtrC

TPtrC (area of memory)

| length, pointer | → | text or binary data |

TPtrC is a constant descriptor through which no data can be modified. All of its member functions (except the constructors) are const.

TPtrC is useful for referencing constant strings or data; for example, accessing text built into ROM resident code, or passing a reference to data in RAM which must not be modified through that reference.

TPtrC is derived from TDesC, which provides a large number of member functions for operating on its content; for example, locating characters within text or extracting portions of data.

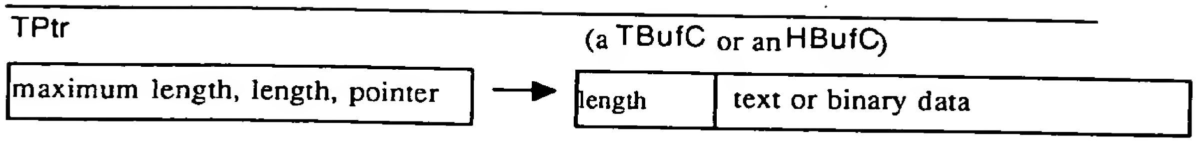
Pointer descriptor - TPtr

E3232.descriptors.buffer-descriptor.TPtr

TPtr (area of memory)

| maximum length, length, pointer | → | text or binary data |

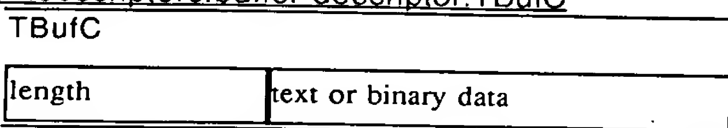
or



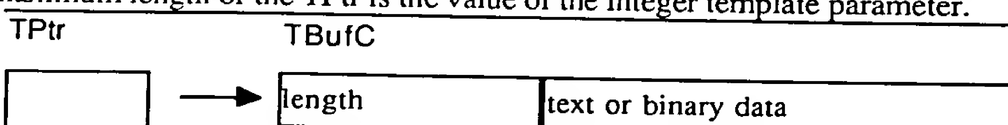
TPtr is a modifiable pointer descriptor through which data can be modified, *provided that the data is not extended beyond the maximum length*. The maximum length is set by the constructor.
TPtr points directly to an area in memory containing the data to be modified.
The maximum number of data items that the area can contain is defined by the maximum length. The length of the TPtr indicates how many data items are currently contained within the data. When this value is less than the maximum, a portion of the data area is unused.
TPtr is useful for constructing a reference to an area of RAM which contains data intended to be modified through that reference, or even to an area of RAM which contains no data yet but in which data will be constructed using the descriptor reference and member functions.
TPtr is also useful for constructing a reference to a TBufC or an HBufC descriptor which contain the data to be modified. A TPtr used in this way points to a TBufC or an HBufC descriptor. The data contained by the TBufC or HBufC descriptors can be modified through the TPtr.
TPtr is derived from TDes which, in turn, is derived from TDesC. Therefore, it inherits all the const member functions defined in TDesC plus the member functions from TDes which can manipulate and *change* the data; for example, appending a character to the end of existing text.

Buffer descriptor - TBufC<TInt S>

E3232.descriptors.buffer-descriptor.TBufC

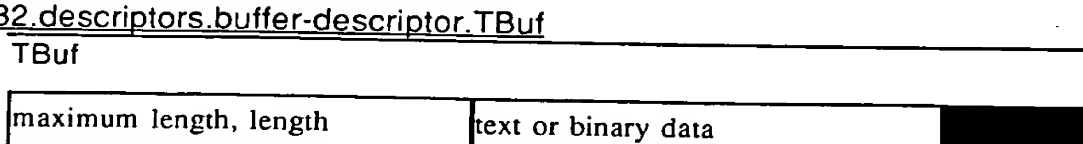


TBufC is a buffer descriptor containing a length followed by the data area. Data can be set into the descriptor at construction time or by the assignment operator (operator=) at *any* other time. Data already held by the descriptor is constant.
The length of a TBufC is defined by an integer template; for example, TBufC<40> defines a TBufC which can contain up to 40 data items.
TBufC is derived from TDesC, which provides a large number of member functions for operating on its content; for example, locating characters within text or extracting portions of data.
TBufC provides the member function, Des(), which creates a modifiable *pointer* descriptor (a TPtr) to reference the TBufC. This allows the TBufC data to be changed through the TPtr. The maximum length of the TPtr is the value of the integer template parameter.



Buffer descriptor - TBuf<TInt S>

E3232.descriptors.buffer-descriptor.TBuf

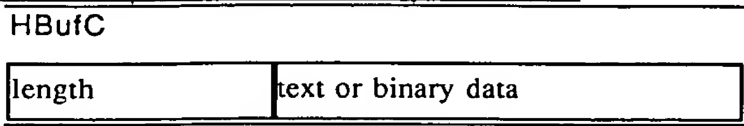


TBuf is a modifiable buffer descriptor containing data which can be modified, *provided that the data is not extended beyond its maximum length.*
The maximum number of data items that the data area within TBuf can contain, is defined by the maximum length. The length of the descriptor indicates how many data items are currently

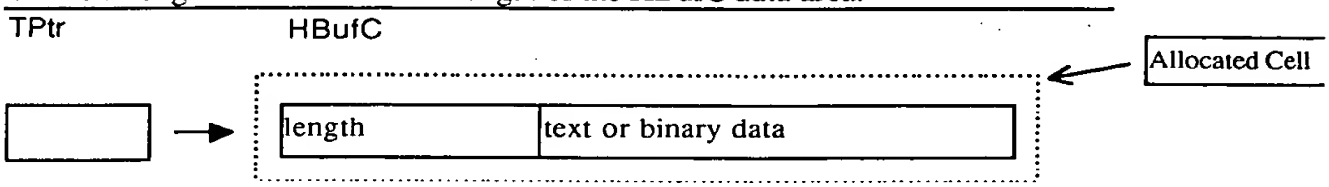
contained within the data area. When this value is less than the maximum, a portion of the data area is unused.
The *maximum length* of a TBuf is defined by an integer template; for example, TBuf<40> defines a TBuf which can contain up to 40 data items (and no more!).
A TBuf is useful for containing data which needs to be manipulated and changed but whose length will not exceed a known maximum; for example, word processor text.
TBuf is derived from TDes which, in turn, is derived from TDesC. Therefore, it inherits all the const member functions defined in TDesC plus the member functions from TDes which can manipulate and *change* the data; for example, appending a character to the end of existing text.

Heap descriptor - HBufC

E3232.descriptors.buffer-descriptor.HBufC



HBufC is a descriptor containing a length followed by data. It is allocated on the heap using the New(), NewL() or NewLC() static member functions. The length of the descriptor is passed as a parameter to these static functions.
Data can be set into the descriptor at construction time or by the assignment operator (operator=) at *any* other time. Data already contained by the descriptor is constant.
HBufC is derived from TDesC, which provides a large number of member functions for operating on its content; for example, locating characters within text or extracting portions of data.
HBufC provides the member function, Des(), which creates a modifiable *pointer* descriptor (a TPtr) to reference the HBufC. This allows the HBufC data to be changed through the TPtr. The maximum length of the TPtr is the length of the HBufC data area.

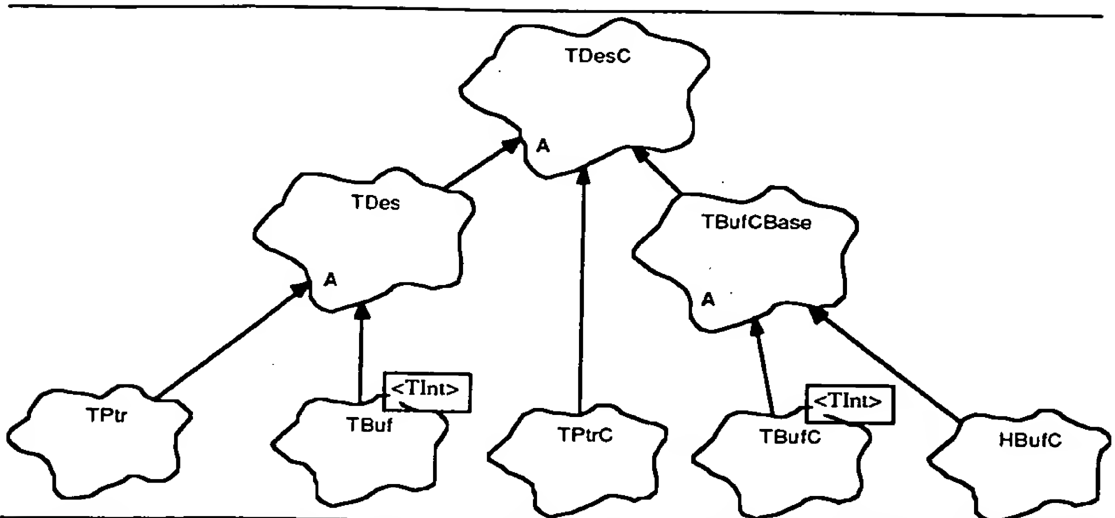


Heap descriptors can be re-allocated. The ReAlloc() or ReAllocL() functions allow the heap descriptor's data area to expand or contract. The length of the data area, however, cannot be made smaller than the length of data currently held. Before contracting the data area, the length of the data held by the descriptor must be reduced.
The length of data which the assignment operator can set into the heap descriptor is limited by the space allocated to the descriptor's data area.
The memory occupied by heap descriptors must be explicitly freed either by calling User::Free() or by using the delete keyword.

The descriptor classes' relationships

E32.descriptors.classes

All of the descriptor classes TPtrC, TPtr, TBufC, TBuf and HBufC are derived from the abstract base classes TDesC and TDes. The class TBufCBase, although marked as an abstract class, is merely an implementation convenience. The following diagram illustrates the relationship between the classes.



The behaviour of the concrete descriptor classes is very similar, and therefore, most of the functionality of descriptors is provided by the abstract base classes.

Because descriptors are widely used (especially on the stack), the size of descriptor objects must be kept to a minimum. To help with this, no virtual functions are defined in order to avoid the overhead of a virtual function table pointer in each descriptor object. As a consequence, the base classes have implicit knowledge of the classes derived from them.

E32 supplies two variants of the descriptor classes, one for handling 8 bit (ASCII) text and binary data and the other for handling 16 bit (UNICODE) text.

The 8 bit variants of the concrete classes are: TPtrC8, TPtr8, TBufC8<TInt S>, TBuf8<TInt S> and HBufC8 while the 8 bit variants of the abstract classes are:- TDesC8, TDes8.

Similarly, the 16 bit variants are named: TPtrC16, TPtr16, TBufC16<TInt S>, TBuf16<TInt S>, HBufC16, TDesC16 and TDes16 respectively.

This distinction is transparent for descriptors intended to represent text. By writing programs which construct and use TPtrC, TPtr, TBufC<TInt S>, TBuf<TInt S> and HBufC classes, compatibility is maintained between both UNICODE and ASCII. The appropriate variant is selected at build time depending on whether the _UNICODE macro has been defined or not. If the _UNICODE macro is defined, the 16 bit variant is used, otherwise the 8 bit variant is used as explained in e32.descriptors.char-set

Descriptors for binary data must *explicitly* use the 8 bit variants; in other words, code must explicitly construct TPtrC8, TPtr8, TBufC8<TInt S>, TBuf8<TInt S> and HBufC8 classes. Explicit use of the 16 bit variants for binary data is possible but not recommended.

In general, 8 bit and 16 bit variants are identical in structure and implementation; the description of the classes themselves uses the build independent names throughout.

N.B. Many member functions take arguments which are either of type TUint8* or type TUint16* depending on whether the descriptor is the 8 bit or 16 bit variant. To simplify explanation, these arguments are written in function prototypes as TUint??*.

Using descriptors for function interfaces

e32.descriptors.using-function-interfaces

Many interfaces which use or manipulate text strings or general binary data use descriptors to specify the interface. In conventional 'C' programming, interfaces would be specified using a combination of char*, void* and length values. In E32 descriptors are always used.

There are four main cases:

- Passing a constant string
  In 'C': StringRead(const char* aString);
  The length of the string is implied by the zero terminator; therefore, the function does not require the length to be explicitly specified.
  In E32: StringRead(const TDesC& aString);

The descriptor contains both the string and its length.

- Passing a string which can be changed.
  In ‘C’: StringWrite(char* aString, int aMaxLength);
  The length of the passed string is implied by the zero terminator. aMaxLength indicates the maximum length to which the string may be extended.
  In E32: StringWrite(TDes& aString);
  The descriptor contains the string, its length and the maximum length to which the string may be extended.
- Passing a buffer containing general binary data
  In ‘C’: BufferRead(const void* aBuffer, int aLength);
  Both the address and length of the buffer must be specified.
  In E32: BufferRead(const TDes8& aBuffer);
  The descriptor contains both the address and the length of the data. The 8 bit variant is explicitly specified; the buffer is treated as byte data, regardless of the build variant.
- Passing a buffer containing general binary data which can be changed.
  In ‘C’:
  BufferWrite(void* aBuffer, int& aLength, int aMaxLength);
  The address of the buffer, the current length of the data and the maximum length of the buffer are specified. The aLength parameter is specified as a reference to allow the function to indicate the length of the data on return.
  In E32: BufferRead(TDes8& aBuffer);
  The descriptor contains the address, the length of the data and the maximum length. The 8 bit variant is explicitly specified; the buffer is treated as byte data, regardless of the build variant.

Folding and collating

e32.descriptors.folding-collating

There are two techniques that may be used to modify the characters in a descriptor prior to performing some operations on text:

- folding
- collating

Variants of member functions that fold or collate are provided where appropriate.

Folding

e32.descriptors.folding

Folding means the removal of differences between characters that are deemed unimportant for the purposes of inexact or case-insensitive matching. As well as ignoring differences of case, folding ignores any accent on a character. By convention, folding converts lower case characters into upper case and removes any accent.

Collating

e32.descriptors.collating

Collating means the removal of differences between characters that are deemed unimportant for the purposes of ordering characters into their collating sequence. For example, collate two strings if they are to be arranged in properly sorted order; this may be different from a strict alphabetic order.

Using descriptors

e32.descriptors.using

The following series of examples show how descriptors can be used. Specifically, the examples illustrate:

- the basic concepts of the pointer descriptors, TPtrC and TPtr. See e32.descriptors.using.pointer-descriptors.

- the basic concepts of the buffer descriptors, TBufC and TBuf. See e32.descriptors.using.buffer-descriptors.
- how descriptors can represent general binary data. See e32.descriptors.using.general-binary-data.
- some of the member functions which do not modify the content of a descriptor. See e32.descriptors.using.non-modifying-functions.
- some of the member functions which modify the content of a descriptor. See e32.descriptors.using.modifying-functions.
- how descriptors can be used in interfaces. See e32.descriptors.using.interface-specifiers.
- the basic concepts of the heap descriptor, HBufC. See e32.descriptors.using.heap-descriptors.

Pointer descriptors

e32.descriptors.using.pointer-descriptors

The code fragments shown here to illustrate the use of pointer descriptors are extracted from the sample source code in the eudesptr project. Run the code in this project to see pointer descriptors in action.

TPtrC

The 8 bit variant

A TPtrC is useful for referencing constant strings or data; for example, accessing text built into ROM resident code, or passing a reference to data in RAM which must not be modified through that reference.

For example, define a constant 'C' style ASCII string:

```
const TText8* cstr8 = (TText8*)"Hello World!";
```

A TPtrC8 descriptor can be constructed to represent this pre-defined area containing the string "Hello World!":

```
TPtrC8 ptrC8(cstr8);
```

The descriptor is separate from the data it represents.

While the length of the 'C' string is 12, its size is 13 to allow for the zero terminator. From the descriptor's viewpoint, both the length and the size of the data is 12. The descriptor uses the length to determine the amount of data represented. The address of the descriptor's data area, as returned by:

```
ptrC8.Ptr();
```

is the same as same as the address of the original 'C' string, cstr8.

The 16 bit variant (UNICODE)

Similarly, define a constant 'C' style string of wide (or UNICODE) characters:

```
const TText16* cstr16 = (TText16*)L"Hello World!";
```

A TPtrC16 descriptor can be constructed to represent this area containing the string of double-byte characters "Hello World!":

```
TPtrC16 ptrC16(cstr16);
```

Again, the descriptor is separate from the data it represents. The length of the descriptor, as returned by a call to ptrc16.Length(), is 12 as it represents 12 text characters but the size, as returned by a call to ptrc16.Size(), is now 24 as each character occupies 2 bytes.

Again, the address of the descriptor's data area, as returned by:

```
ptrc16.Ptr();
```

is the same as the address of the original 'C' string, cstr16.

The _S macro and build independent names

Use the _S macro to define a constant 'C' style string of the appropriate width. The TText variant is defined at build time (as either TText8 or TText16) depending on whether the _UNICODE macro has been defined. For example:

```
const TText* cstr = _S("Hello World!");
```

The TPtrC descriptor:

TPtrC ptrc(cstr);

represents the area containing the text "Hello World!"; the TPtrC variant is defined at build time (as either TPtrC8 or TPtrC16) depending on whether the _UNICODE macro has been defined.

The length of the descriptor, as returned by ptrc.Length(), is 12 for all build variants but the size of the descriptor, as returned by ptrc.Size() is 12 for an ASCII build and 24 for a UNICODE build.

See e32.macro._S.

The _L macro

The _L macro constructs a TPtrC of the correct variant and is frequently used as a source descriptor when constructing a buffer descriptor or a heap descriptor.

The macro is also useful for constructing a TPtrC to be passed as a parameter to a function. For example, the Printf() member function of the RTest class used in these examples requires a descriptor as its first parameter. Here, the _L macro constructs a TPtrC representing the constant static area generated by the compiler containing the text "\nThe _L macro constructs a TPtrC".

```
testConsole.Printf(_L("\nThe _L macro constructs a TPtrC"));
```

See e32.macro._L.

TPtr

A TPtr is a modifiable pointer descriptor through which data can be modified, *provided that the data is not extended beyond the maximum length.* The maximum length is set by the constructor.

For example, define a TText area initialised to contain the string "Have a nice day":

```
TText str[16] =  {'H', 'a', 'v', 'e', ' ', 'a',
                  ' ', 'n', 'i', 'c', 'e',
                  ' ', 'd', 'a', 'y', '\0'};
```

A TPtr descriptor can be constructed to represent the data in this area; further, this data can be changed, contracted and expanded provided that the length of the data does not exceed the maximum.

```
TPtr ptr(&str[0],15,16);
```

The descriptor ptr represents the data in str and is constructed to have a current length of 15 (the length of the text, excluding the zero terminator) and a maximum length of 16 (the actual length of str). Once the descriptor has been constructed, it has no further use for the zero terminator.

The data can be completely replaced using the assignment operator:

```
ptr = _L("Hi there");
```

Note the use of the _L macro to construct a TPtrC of the correct build variant as the source of the assignment.

The length of ptr is now 8 but the maximum length remains 16. The size depends on the build variant. In an ASCII build, this is 8 but in a UNICODE build, this becomes 16 (two bytes for every character).

The length of the data represented can be changed. For example, after ptr.SetLength(2), the descriptor represents the text "Hi". The length can even be set to zero so that after ptr.Zero(), the descriptor represents no data. Nevertheless, the maximum length remains at 16 so that:

```
ptr = _L("Have a nice day!");
```

puts the 16 characters "Have a nice day" into the descriptor's data area.

See also e32.macro._L.

Buffer descriptors

e32.descriptors.using.buffer-descriptors

The code fragments shown here to illustrate the use of buffer descriptors are extracted from the sample source code in the **eudesbuf** project. Run the code in this project to see buffer descriptors in action.

TBufC

A TBufC is a buffer descriptor where the data area is part of the descriptor itself.
Data can be set into the descriptor at construction time or by the assignment operator at *any* other time. Data already held by the descriptor cannot be modified but it can be completely replaced (again, using the assignment operator).
For example:

```
TBufC<16> bufc2(_L("Hello World!"));
```

constructs a TBufC which can contain up to 16 data items. During construction, the descriptor's data area is set to contain the text "Hello World!" and the length of the descriptor is set to 12.
The data within bufc2 cannot be modified but it can be replaced using the assignment operator:

```
bufc2 = _L("Replacement text");
```

To prevent any possibility of replacing the data, declare bufc2 as const.
The data within a TBufC *can* be changed by constructing a TPtr from the TBufC using the Des() member function; the data can then be changed through the TPtr. The maximum length of the TPtr is the value of the TBufC template parameter. For example:

```
bufc2 = _L("Hello World!");
TPtr ptr = bufc2.Des();
ptr.Delete((ptr.Length()-1),1);
ptr.Append(_L(" & Hi"));
```

This deletes the last character in the TBufC and adds the characters " & Hi" so that the TBufC now contains the text "Hello World & Hi" and its length is 16. Note that the length of both the TBufC and the TPtr reflect the changed data.

TBuf

A TBuf is a modifiable buffer descriptor where the data area is part of the descriptor itself. The data can be modified *provided that the data is not extended beyond the maximum length.* The maximum length is set by the constructor.
For example:

```
TBuf<16> buf(_L("Hello World!"));
```

constructs a TBuf which can contain up to 16 data items. During construction, the descriptor's data area is set to contain the text "Hello World!", the length of the descriptor is set to 12 and its maximum length is set to 16.
The data can be modified directly:

```
buf.Append('@');
```

changes buf's data to "Hello World!@" and its length to 13 while:

```
buf.SetLength(3);
```

changes it length to 3 and its data to "Hel".
The maximum length of the descriptor always remains at 16.
Like a TBufC descriptor, the data contained within a TBuf can be replaced entirely using the assignment operator:

```
buf = _L("Replacement text");
```

replaces "Hello World" with "Replacement text" and changes the length of the descriptor to 16.
An attempt to increase the length of the data beyond the maximum generates an exception (a panic). For example:

```
buf = _L("Text replacement causes panic!");
```

generates a panic at run time because the length of the replacement text (30) is greater than the maximum (16).

General binary data

e32.descriptors.using.general-binary-data

The code fragments shown here, illustrating how descriptors can handle general binary data, are extracted from the sample source code in the **eudesbin** project. Run the code in this project to see the sample in action.

The kind of data represented or contained by descriptors is not restricted to text. Descriptors can also handle general binary data.
To deal with general binary data, always explicitly construct an 8 bit variant descriptor. Binary data should always be treated as 8 bit data regardless of the build.
For example set up an area in memory initialised with binary data:

```
TUint8 data[6] = {0x00,0x01,0x02,0xAD,0xAE,0xAF};
```

Construct a modifiable buffer descriptor using the default constructor:

```
TBuf8<32> buffer;
```

The following code extracted from the eudesbin project puts the binary data into the descriptor, appends a number of single byte values and then displays the data at the test console. The length of the buffer is 9, the maximum length is 32 and the size is 9 regardless of the build.

```
TInt index;
TInt counter;
buffer.Append(&data[0],sizeof(data));
buffer.Append(0xFD);
buffer.Append(0xFE);
buffer.Append(0xFF);
counter = buffer.Length();
for (index = 0; index < counter; index++)
    testConsole.Printf(_L("0x%02x "),buffer[index]);

testConsole.Printf(_L("; Length()=%d;\n"),
                   buffer.Length()
                  );
testConsole.Printf(_L("Size()=%d; MaxLength()=%d\n"),
                   buffer.Size(),
                   buffer.MaxLength()
                  );
```

Text and general binary data can be freely mixed; so that:

```
buffer.Append('A');
buffer.Append('B');
buffer.Append(0x11);
```

is acceptable.

Non-modifying functions

e32.descriptors.using.non-modifying-functions

The code fragments shown here, illustrating some of the non-modifying descriptor member functions, are extracted from the sample source code in the eudesc project. Look at the code in this project to see the full set of examples
These examples all use a TBufC descriptor constructed to contain the text “Hello World!”. Note also that the descriptor is declared const so that its data cannot be replaced using the assignment operator:

```
const TBufC<16> bufc(_L("Hello World!"));
```

Right() & Mid()

These functions construct a TPtrc to represent a portion of bufc’s data.

```
TPtrC ptrc1 = bufc.Right(5);
```

ptrc1 represents the right hand 5 data items in bufc. ptrc1’s data is "orld!", its length is 5 and the address of its data area is the address of bufc’s data area plus 7.
The Left() member function works in a similar way.

```
TPtrC ptrc2 = bufc.Mid(3,6);
```

ptrc2 represents the 6 data items offset 3 from the start of bufc’s data area. ptrc2’s data is “lo Wor”, its length is 6 and the address of its data area is the address of bufc’s data area plus 3.

In practice, it may not be necessary to assign the returned TPtrC to another TPtrC. For example, the following code puts a value of 3 in pos; this is the offset of char 'W' within the chars "lo Wor" (see later for an explicit example of Locate())

```
TInt pos;
...
pos = (bufc.Mid(3,6)).Locate('W');
```

These functions can panic. For example, requesting the 13 right hand data items in bufc will cause an exception (there are only 12):

```
TPtrC ptrc3 = bufc.Right(13);
```

Compare() & CompareF()

The compare functions can be used to compare the content of two descriptors. Any kind of data can be compared. For binary data, use Compare(). For text use Compare(), CompareF() or CompareC().

The following example compares the content of bufc with the content of a number of descriptors and displays the results at the test console:

```
...
TInt index;
...
TPtrC        genptr;
const TBufC<19> lessthan(_L(" is less than    "));
const TBufC<19> greaterthan(_L(" is greater than "));
const TBufC<19> equalto(_L(" is equal to     "));
...
const TBufC<16> compstr[7] =    {_L("Hello World!@@"),
                                 _L("Hello"),
                                 _L("Hello Worl"),
                                 _L("Hello World!"),
                                 _L("hello world!"),
                                 _L("Hello World "),
                                 _L("Hello World@")
                                };
for (index = 0; index < 7; index++)
      {
      if ( (bufc.Compare(compstr[index])) < 0 )
            genptr.Set(lessthan);
      else if ( (bufc.Compare(compstr[index])) > 0)
                  genptr.Set(greaterthan);
            else genptr.Set(equalto);

      testConsole.Printf(_L("\"%S\"%S\"%S\"\n"),
                              &bufc,
                              &genptr,
                              &compstr[index]
                             );
      }
```

The case of text is important using Compare(); the fourth comparison is equal but the fifth comparison is not (the 'w' characters are a different case).

Using CompareF(), the case is not important; both the fourth and fifth comparisons return an equal result.

Locate(), LocateF() & LocateReverse()

The locate functions can be used to find the position (offset) of a character within text or a specific value within general binary data.

The following example attempts to find the positions (i.e. the offsets) of the characters 'H', '!', 'o' and 'w' within the text "Hello World!" and displays the result at the test console:

```
...
```

```
TInt  index;
TInt  pos;
TPtrC genptr;

const TBufC<9>  notfound(_L("NOT FOUND"));
const TBufC<5>  found(_L("found"));
...
TChar  ch[4]  =  {'H', '!', 'o', 'w'};
...
testConsole.Printf(_L("using Locate() \n"));

for (index = 0  ; index < 4; index++)
        {
        pos = bufc.Locate(ch[index]);

        if (pos < 0)
                genptr.Set(notfound);
        else
                genptr.Set(found);

        testConsole.Printf(_L("\"%S\"  Char %c is at pos %d (%S)\n"),
                                    &bufc,
                                    ch[index],
                                    pos,
                                    &genptr
                                    );
        }
```

The character 'w' is not found using Locate() but is found using LocateF(). This is because Locate() is case sensitive while LocateF().

This example uses LocateReverse() which is used to find the position of a character starting from the end of the descriptor's data area

```
...
testConsole.Printf(_L("using LocateReverse() \n"));

for (index = 0  ; index < 4; index++)
        {
        pos = bufc.LocateReverse(ch[index]);

        if (pos < 0)
                genptr.Set(notfound);
        else
                genptr.Set(found);

        testConsole.Printf(_L("\"%S\"  Char %c is at pos %d (%S)\n"),
                                    &bufc,
                                    ch[index],
                                    pos,
                                    &genptr
                                );
        }
```

Note that the 2nd char 'o' in the string "Hello World!" is found this time.

Match() & MatchF()

The following example shows the use of the Match() and MatchF() member functions. The result of a matches between the content of buf and a series of descriptors with varying combinations of match strings is displayed at the test console.

```
...
```

```
TInt  index;
TInt  pos;
TPtrC genptr;

const TBufC<9>  notfound(_L("NOT FOUND"));
const TBufC<5>  found(_L("found"));
...
TBufC<8> matchstr[7] =       {_L("*World*"),
                              _L("*W?rld*"),
                              _L("Wor*"),
                              _L("Hello"),
                              _L("*W*"),
                              _L("hello*"),
                              _L("*")
                              };
for (index = 0  ; index < 7; index++)
      {
      pos = bufc.Match(matchstr[index]);
      if (pos < 0)
            genptr.Set(notfound);
      else
            genptr.Set(found);

      testConsole.Printf(_L("%- 8S   pos %2d  (%S)\n"),
                              &matchstr[index],
                              pos,
                              &genptr
                         );
      }
```

Note that when using MatchF(), the result is different when matching the 6th string where the case is ignored.

Modifying functions

e32.descriptors.using.modifying-functions

The code fragments shown here, illustrating some of the modifying descriptor member functions, are extracted from the sample source code in the eudes project. Look at the code in this project to see the full set of examples.

These examples all use a TBuf descriptor constructed to contain the text "Hello World!".:

```
TBuf<32> buf(_L("Hello World!"));
```

Swap()

The contents, length and size of altbuf1 and buf are swapped; the maximum lengths of the descriptors do NOT change.

```
TBuf<16> altbuf1(_L("What a nice day"));
...

buf.Swap(altbuf1);
```

Repeat()

The current length of buf is set to 16. Repeat copying the characters "Hello" generates the text sequence "HelloHelloHelloH" in buf.

```
buf.SetLength(16);
buf.Repeat(_L("Hello"));
```

Setting the length of buf to and re-doing the repeat generates the text sequence "HelloHel".

Justify()

The example uses src as the source descriptor.

```
TBufC<40> src(_L("Hello World!"));
...
```

```
buf.Justify(src,16,ELeft,'@');
```
The descriptor src has length 12.
The target field in buf has width 16 (this is greater than the length of the descriptor src). src is copied into the target field, aligned left and padded with '@' characters. The length of buf becomes the same as the specified width, i.e 16.

```
buf.Justify(src,16,ECenter,'@');
```
The target field in buf has width 16 (this is greater than the length of the descriptor src). src is copied into target field, aligned centrally and padded with '@' characters. The length of buf becomes the same as the specified width, i.e 16

```
buf.Justify(src,10,ECenter,'@');
```
The target field in buf has width 10 (this is smaller than the length of the descriptor src). src is copied into the target field but truncated to 10 characters and, therefore, alignment and padding information is not used. The length of buf becomes the same as the width, i.e. 10

```
buf.Justify(src,KDefaultJustifyWidth,ECenter,'@');
```
The target field in buf is set to the length of the descriptor src (whatever it currently is). src is copied into the target field. No padding and no truncation is needed and so the alignment and padding information is not used. The length of buf becomes the same as the length of src, i.e. 12.

Descriptors as interface specifiers

e32.descriptors.using.interface-specifiers

See the eudesint project for examples illustrating the use of descriptors in function interfaces.

Heap descriptors

e32.descriptors.using.heap-descriptors

The code fragments shown here, illustrating the use of heap descriptors, are extracted from the sample source code in the eudeshbc project. Look at the code in this project to see the the sample in action.

An HBufC is always constructed on the heap using the static member functions New(), NewL() or NewLC(). For example:

```
HBufC* buf;
...
buf = HBufC::NewL(15);
```
This constructs an HBufC which can hold up to 15 data items. The current length is zero.

Although existing data within an HBufC cannot be modified, the assignment operator can be used to replace that data. For example:

```
*buf = _L("Hello World!");
```
To allow more than 15 characters or data items to be assigned into the HBufC, it must be reallocated first. For example:

```
buf = buf->ReAllocL(20);
```
This permits the following assignement to be done without causing a panic:

```
*buf = _L("Hello World! Morning");
```
buf may or may not point to a different location in the heap after reallocation. The location of the reallocated descriptor depends on the heap fragmentation and the size of the new cell.

The Des() function returns a TPtr to the HBufC.The data in the HBufC can be modified through the TPtr. The maximum length of the TPtr is determined from the size of the cell allocated to the data-area of the HBufC. For example:

```
TPtr ptr = buf->Des();
...
ptr.Delete((ptr.Length()-9),9);
ptr.Append(_L(" & Hi"));
```
This changes the data in the HBufC and the length of the HBufC.

TPtrC class — Constant pointer descriptor

Overview

Derivation

TDesC Abstract: implements descriptor behaviour which does not modify data.
TPtrC A constant pointer descriptor.

Defined in

e32des8.h for the 8 bit variant (TPtr8).
e32des16.h for the 16 bit variant (TPtr16).

Description

Create a TPtrC descriptor to access a pre-existing location in either ROM or RAM where the data at that location is to be accessed but not changed (or where the data *cannot* be changed).
A common use for a TPtrC is to access a string of text in a code segment. This will normally be constructed using the _L macro which constructs a TPtrC descriptor for either an ASCII or UNICODE build.
Often, a TPtrC will appear as the right hand side of an expression or as an initialisation value for another descriptor, for example:

```
TBuf<16> str(_L("abcdefghijklmnop"));
...
str.Find(_L"abc");
str.Find(_L"bcde");
```

The _L macro expands to a TPtrC which is defined as either a TPtrC8 or TPtrC16 depending on the build variant (TBuf is also defined in a similar way).
The 8 bit variant, TPtrC8 can be constructed to access binary data. The 8 bit variant is always explicitly used for binary data.
Five constructors are available to build a TPtrC and include a default constructor. A TPtrC can be (re-)initialised after construction by using the set() functions.
All the member functions described under the TDesC class are available for use by a TPtrC descriptor. In summary these are:

Length()	Fetch length of descriptor data.
Size()	Fetch the number of bytes occupied by descriptor data.
Ptr()	Return a pointer to the descriptor data.
Compare(), CompareF(), CompareC()	Compare data (normally), (folded),(collated).
Match(),MatchF(),MatchC()	Pattern match data (normally), (folded), (collated).
Locate(),LocateF()	Locate a character in forwards direction (normally), (folded).
LocateReverse(), LocateReverseF()	Locate a character in reverse direction (normally), (folded).
Find(),FindF(),FindC	Find data (normally), (folded), (collated).
Left()	Construct TPtrC for leftmost part of data.
Right()	Construct TPtrC for rightmost part of data.
Mid()	Construct TPtrC for portion of data.
Alloc(),AllocL(),AllocLC()	Construct an HBufC for *this* descriptor.
HufEncode()	Huffman encode
HufDecode()	Huffman decode
operators < <= > >= ==	Comparison operators
operator []	Indexing operator

Construction

e32.descriptors.TPtrC.construction

TPtrC() Default C++ constructor

TPtrC();

Description

The default C++ constructor is used to construct a constant pointer descriptor.
The length of the constructed descriptor is set to zero and its pointer is set to NULL.

Notes

Use the Set() member function to initialise the pointer descriptor.

TPtrC() Copy constructor

TPtrC(const TPtrC& aDes);

Description

The C++ copy constructor constructs a new TPtrC object from the existing one.
The length of the constructed descriptor is set to the length of aDes and is set to point to aDes's. data.

TPtrC() C++ constructor [with any descriptor]

TPtrC(const TDesC& aDes);

Description

The C++ constructor is used to construct the TPtrC with any kind of descriptor.
The length of the constructed descriptor is set to the length of aDes, and it is set to point to aDes's data.

Arguments

const TDesC& aDes	A reference to any type of descriptor used to construct the TPtrC.

Notes

If aDes is a reference to a heap descriptor (HBufC), then the data also resides on the heap.

TPtrC() C++ constructor [with zero terminated string]

TPtrC(const TText* aString);

Description

The C++ constructor is used to construct the TPtrC object with a zero terminated string.
The length of the descriptor is set to the length of the zero terminated string, excluding the zero terminator.
The constructed descriptor is set to point to the location of the string, whether in RAM or ROM.

Arguments

const TText* aString	A pointer to the zero terminated used to construct the TPtrC.

TPtrC() C++ constructor [with address and length]

TPtrC(const TUint??* aBuf,TInt aLength);

Description

The C++ constructor is used to construct the TPtrC with the memory address and length.
The length of the constructed descriptor is set to the value of aLength.
The constructed descriptor is set to point to the memory address supplied in aBuf; the address can refer to RAM or ROM.

Arguments

const TUint??* aBuf	The address which is to be the data area of the constant pointer descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.

TInt aLength	The length of the constructed constant pointer descriptor. This value must be non-negative otherwise the constructor will panic with ETDes8LengthNegative for the 8 bit variant or ETDes16LengthNegative for the 16 bit variant.

Late initialisation

e32.descriptors.TPtrC.late-initialisation

Set() — Initialisation taking any descriptor

void Set(const TDesC& aDes);

Description

Use this function to initialise (or re-initialise) a constant pointer descriptor using the content of any kind of descriptor.

The length of this constant pointer descriptor is set to the length of aDes.

This descriptor is set (or re-set) to point to aDes's data.

Arguments

const TDesC& aDes	A reference to any descriptor whose content is to be used to initialise *this* constant pointer descriptor.

Notes

The Set() function can be used to initialise a constant pointer descriptor constructed using the default constructor.

If aDes is a reference to a heap descriptor (HBufC), then the data also resides on the heap.

Set() — Initialisation taking address and length

void Set(const TUint??* aBuf,TInt aLength);

Use this function to initialise (or re-initialise) a constant pointer descriptor using the supplied memory address and length.

The length of this constant pointer descriptor is set to the value of aLength.

The descriptor is set to point to the memory address supplied in aBuf; the address can refer to RAM or ROM.

Arguments

const TUint??* aBuf	The address which is to be the data area of the constant pointer descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLength	The length of the constant pointer descriptor. This value must be non-negative otherwise the constructor will panic with ETDes8LengthNegative for the 8 bit variant or ETDes16LengthNegative for the 16 bit variant.

Notes

The Set() function can be used to initialise a constant pointer descriptor constructed using the default constructor.

TPtr class — Modifiable pointer descriptor

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.
TDes	Abstract: implements descriptor behaviour which can change data.
TPtr	A modifiable pointer descriptor.

Defined in

e32des8.h	for the 8 bit variant (TPtr8).
e32des16.h	for the 16 bit variant (TPtr16).

Description

Create a TPtr descriptor to access a pre-existing area or buffer in RAM where the contents of that buffer are to be accessed and manipulated.

A common use for a TPtr is to access the buffer of an existing TBufC or an HBufC descriptor using the Des() member functions (of TBufC and HBufC). For example:

```
TBufC<8> str(_L("abc"));

str.Des().Append('x');
```

A TPtr is defined as either a TPtr8 or TPtr16 depending on the build variant and can be used to access text.

The 8 bit variant, TPtr8 can be constructed to access binary data. The 8 bit variant is always explicitly used for binary data.

Two constructors are available to build a TPtr and include a default constructor. A TPtr can be (re-)initialised after construction by using the set() functions.

All the member functions described under the TDesC and TDes classes are available for use by a TPtr descriptor. In summary these are:

Length()	Fetch length of descriptor data.
Size()	Fetch the number of bytes occupied by descriptor data.
Ptr()	Fetch address of descriptor data.
Compare(), CompareF(), CompareC()	Compare data (normally), (folded),(collated).
Match(), MatchF(), MatchC()	Pattern match data (normally), (folded), (collated).
Locate(), LocateF()	Locate a character in forwards direction (normally), (folded).
LocateReverse(), LocateReverseF()	Locate a character in reverse direction (normally), (folded).
Find(), FindF(), FindC	Find data (normally), (folded), (collated).
Left()	Construct TPtrC for leftmost part of data.
Right()	Construct TPtrC for rightmost part of data.
Mid()	Construct TPtrC for portion of data.
Alloc(), AllocL(), AllocLC()	Construct an HBufC for *this* descriptor.
HufEncode()	Huffman encode
HufDecode()	Huffman decode
MaxLength()	Fetch maximum length of descriptor.
MaxSize()	Fetch maximum size of descriptor
SetLength()	Set length of descriptor data
Zero()	Set length of descriptor data to zero
SetMax()	Set length of descriptor data to the maximum value.
Swap()	Swap data between two descriptors.
Copy(), CopyF(), CopyC()	Copy data (normally), (and fold), (and collate).
CopyLC()	Copy data and convert to lower case.
CopyUC()	Copy data and convert to upper case
CopyCP()	Copy data and capitalise
Repeat()	Copy and repeat.
Justify()	Copy and justify.
Insert()	Insert data.
Delete()	Delete data.
Replace()	Replace data.
TrimLeft()	Delete spaces from left side of data area.
TrimRight()	Delete spaces from right side of data area.
Trim()	Delete spaces from both left and right side of data area.
Fold()	Fold characters.
Collate()	Collate characters.
LowerCase()	Convert to lower case.
UpperCase()	Convert to upper case.

Capitalise()	Capitalise.
Fill()	Fill with specified character.
FillZ()	Fill with 0x00.
Num()	Convert numerics to character (hex.digits to lower case).
NumUC()	Convert numerics to (upper case) character.
Format(), FormatList()	Convert multiple arguments to character according to format specification.
Append()	Append data.
AppendFill()	Append with fill characters.
AppendJustify()	Append data and justify
AppendNum()	Append from converted numerics.
AppendNumUC()	Append from converted numerics; convert to upper case.
AppendFormat(), AppendFormatList()	Append from converted multiple arguments.
ZeroTerminate()	Append zero terminator.
PtrZ()	Append zero terminator and return a pointer.
operators < <= > >= ==	Comparison operators.
operator +=	Appending operator.
operator []	Indexing operator.

Construction

e32.descriptors.TPtr.construction

TPtr() C++ constructor [with address and maximum length]

TPtr(TUint??* aBuf,TInt aMaxLength);

Description

The C++ constructor is used to construct the TPtr with the address and maximum length.
The length of the constructed descriptor is set to zero and its maximum length is set to aMaxLength.
The constructed descriptor is set to point to the memory address supplied in aBuf which can refer either to RAM or ROM.

Arguments

TUint??* aBuf	The address which is to be the data area of the modifiable pointer descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aMaxLength	The maximum length of the new modifiable pointer descriptor. This value must be non-negative otherwise the constructor will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for the 16 bit variant.

TPtr() C++ constructor [with address, length and maximum length]

TPtr(TUint??* aBuf,TInt aLength,TInt aMaxLength);

Description

The C++ constructor is used to construct the TPtr with the address, length and maximum length.
Use this to construct a modifiable pointer descriptor using the supplied memory address, length and maximum length to initialise it.
The length of the constructed descriptor is set to aLength and its maximum length is set to aMaxLength.
The constructed descriptor is set to point to the memory address supplied in aBuf which can refer either to RAM or ROM.

Arguments

TUint??* aBuf	The address which is to be the data area of the modifiable pointer descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
Tint aLength	The length of the new modifiable pointer descriptor. This value must be non-negative *and* not greater than the value of aMaxLength otherwise the constructor will panic with ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRange for 16 bit variant.
TInt aMaxLength	The maximum length of the new modifiable pointer descriptor. This value must be non-negative otherwise the constructor will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for 16 bit variant.

Late initialisation

e32.descriptors.TPtr.late-initialisation

Set() Initialisation by copying a TPtr

void Set(TPtr& aPtr);

Use this function to initialise (or re-initialise) a modifiable pointer descriptor using the content of another modifiable pointer descriptor. The function behaves as a copy constructor.

The length of the descriptor is set to the length of aPtr and its maximum length is set to the maximum length of aPtr.

The descriptor is set (or re-set) to point to aPtr's data.

Arguments

TPtr& aPtr	A reference to a modifiable pointer descriptor whose content is to be used to initialise *this* modifiable pointer descriptor.

Set() Initialisation taking address, length and maximum length

void Set(TUint??* aBuf,TInt aLength,TInt aMaxLength);

Use this function to initialise (or re-initialise) a modifiable pointer descriptor using the supplied memory address, length and maximum length.

The length of the resulting descriptor is set to the value of aLength and its maximum length is set to the value of aMaxLength.

The descriptor is set (or re-set) to point to the memory address supplied in aBuf; the address can refer to RAM or ROM.

Arguments

TUint??* aBuf	The address which is to be the data area of the modifiable pointer descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
Tint aLength	The length of the modifiable pointer descriptor. This value must be non-negative *and* not greater than the value of aMaxLength otherwise the constructor will panic with ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRange for the 16 bit variant
TInt aMaxLength	The maximum length of the modifiable pointer descriptor. This value must be non-negative otherwise the constructor will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for the 16 bit variant

Assignment operators

e32.descriptors.TPtr.assignment-operators

See also e32.descriptors.TDes.assignment-operators.

operator = — Operator = taking a TPtr

TPtr& operator=(const TPtr& aDes);

Description

This assignment operator copies a modifiable pointer descriptor to *this* modifiable pointer descriptor.

aDes's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TPtr& aDes	A reference to the modifiable pointer descriptor whose data is to be copied.

Return value

TPtr&	A reference to *this* descriptor.

Notes

The length of aDes must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

operator = — Operator = taking any descriptor

TPtr& operator=(const TDesC& aDes);

Description

This assignment operator copies the content of any type of descriptor, aDes, to *this* modifiable pointer descriptor.

aDes's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose data is to be copied.

Return value

TPtr&	A reference to *this* descriptor.

Notes

The length of aDes must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

operator = — Operator = taking a zero terminated string

TPtr& operator=(const TText* aString);

Description

This assignment operator copies a zero terminated string, excluding the zero terminator, into *this* modifiable pointer descriptor.

The copied string replaces the existing content of *this* descriptor.

The length of *this* descriptor is set to the length of the string (excluding the zero terminator).

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Return value

TPtr&	A reference to *this* descriptor.

Notes

The length of the string, excluding the zero terminator, must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

TBufC<TInt S> class — Constant buffer descriptor

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.

TBufCBase	Abstract: implementation convenience.
TBufC<TInt S>	A constant buffer descriptor.

Defined in

e32des8.h	for the 8 bit variant (TBufC8<TInt S>).
e32des16.h	for the 16 bit variant (TBufC16<TInt S>)

Description

Create a TBufC descriptor to provide a buffer of *fixed* length for containing and accessing constant data.

The data held in a TBufC descriptor cannot be modified, although it can be replaced.

Four constructors are available to build a TBufC descriptor and include a default constructor.

The content of TBufC descriptor can be replaced after construction using the assignment operators.

For example, to create a buffer of length 16 set to contain the characters "ABC"

```
TBufC<16> str(_L("ABC"));
```

The content cannot be modified but may be replaced, for example:

```
str = _L("xyz");
```

To create a buffer which is intended to contain general binary data, explicitly construct the 8 bit variant of TBufC; for example, to create a 256 byte buffer:

```
TBufC8<256> buf;
...
buf = ...;
```

All the member functions described under the TDesC class are available for use by a TBufC descriptor. In summary these are:

Length()	Fetch length of descriptor data.
Size()	Fetch the number of bytes occupied by descriptor data.
Ptr()	Fetch address of descriptor data.
Compare(), CompareF(), CompareC()	Compare data (normally), (folded),(collated).
Match(),MatchF(),MatchC()	Pattern match data (normally), (folded), (collated).
Locate(),LocateF()	Locate a character in forwards direction (normally), (folded).
LocateReverse(), LocateReverseF()	Locate a character in reverse direction (normally), (folded).
Find(),FindF(),FindC	Find data (normally), (folded), (collated).
Left()	Construct TPtrC for leftmost part of data.
Right()	Construct TPtrC for rightmost part of data.
Mid()	Construct TPtrC for portion of data.
Alloc(),AllocL(),AllocLC()	Construct an HBufC for *this* descriptor.
HufEncode()	Huffman encode
HufDecode()	Huffman decode
operators < <= > >= ==	Comparison operators
operator []	Indexing operator

Construction

e32.descriptors.TBufC.construction

TBufC() — Default C++ constructor

TBufC();

Description

The default C++ constructor is used construct a non-modifiable buffer descriptor.

The integer template parameter<TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the descriptor object.

The length of the constructed descriptor is set to zero.

Notes
Use the assignment operators to initialise the non-modifiable buffer descriptor.

TBufC() — Copy constructor
TBufC(const TBufC<S>& aLcb);

Description
The C++ copy constructor constructs a new TBufC<S> object from the existing one.
The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.
aLcb's data is copied into the constructed descriptor's data area.
The length of the constructed descriptor is set to the length of aLcb.

TBufC() — C++ constructor [with any descriptor]
TBufC(const TDesC& aDes);

Description
The C++ constructor is used to construct the TBufC<S> with any kind of descriptor.
The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.
aDes's data is copied into the constructed descriptor's data area.
The length of the constructed descriptor is set to the length of aDes.

Arguments
const TDesC& aDes	A reference to any type of descriptor used to construct the TBufC<S>.

Notes
The length of aDes must not be greater than the value of the integer template parameter <TInt S> otherwise the constructor will panic with ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRange for the 16 bit variant.

TBufC() — C++ constructor[with zero terminated string]
TBufC(const TText* aString);

Description
The C++ constructor is used to construct the TBufC<S> with a zero terminated string.
The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor object.
The string, excluding the zero terminator, is copied into the constructed descriptor's data area.
The length of the constructed descriptor is set to the length of the string, excluding the zero terminator.

Arguments
const TText* aString	The address of the zero terminated string used to construct the TBufC<S>.

Notes
The length of the string, excluding the zero terminator, must not be greater than the value of the integer template parameter <TInt S> otherwise the constructor will panic with ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRange for the 16 bit variant.

Create a modifiable pointer descriptor
e32.descriptors.TBufC.create-TPtr

Des() — Create & return a TPtr
TPtr Des();

Description
Use this function to construct and return a modifiable pointer descriptor to represent *this* descriptor.

The content of a non-modifiable buffer descriptor cannot be altered but creating a modifiable pointer descriptor provides a mechanism for modifying that data.
The length of the new TPtr is set to the length of *this* descriptor.
The maximum length of the new TPtr is set to the value of the integer template parameter <TInt S>.
The new TPtr is set to point to *this* descriptor. *This* descriptor's data is neither copied nor moved.
This descriptor's data can be modified through the newly constructed TPtr. If there is any change to the length of the data, then the length of both this descriptor and the TPtr is modified to reflect that change.

Return value

TPtr	A modifiable pointer descriptor representing *this* non-modifiable buffer descriptor.

Assignment operators

e32.descriptors.TBufC.assignment-operators

See also e32.descriptors.TDes.assignment-operators.

operator = — Operator = taking a TBufC<S>

TBufC<S>& operator=(const TBufC<S>& aLcb);

Description

This assignment operator copies the content of the non-modifiable buffer descriptor aLcb into *this* non-modifiable buffer descriptor.
aLcb's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aLcb.

Arguments

const TBufC<S>& aLcb	A reference to a non-modifiable buffer descriptor whose content is to be copied.

Return value

TBufC<S>&	A reference to *this* descriptor.

operator = — Operator = taking any descriptor

TBufC<S>& operator=(const TDesC& aDes);

Description

This assignment operator copies the content of any type of descriptor aDes into *this* non-modifiable buffer descriptor.
aDes's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TDesc& aDes	A reference to any type of descriptor whose data is to be copied.

Return value

TBufC<S>&	A reference to *this* descriptor.

Notes

The length of aDes must not be greater than the value of the integer template parameter <TInt S> otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

operator = — Operator = taking zero terminated string

TBufC<S>& operator=(const TText* aString);

Description

This assignment operator copies a zero terminated string, excluding the zero terminator, into *this* non-modifiable buffer descriptor.
The copied string replaces the existing content of *this* descriptor. The length of *this* descriptor is set to the length of the string, excluding the zero terminator.

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Return value

TBufC<S>&	A reference to *this* descriptor.

Notes

The length of the string, excluding the zero terminator, must not be greater than the value of the template parameter <TInt S> otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

TBuf<TInt S> class — Modifiable buffer descriptor

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.
TDes	Abstract: implements descriptor behaviour which can change data.
TBuf<TInt S>	A modifiable buffer descriptor.

Defined in

e32des8.h for the 8 bit variant (TBuf<TInt S>).

e32des16.h for the 16 bit variant (TBuf<TInt S>).

Description

Create a TBuf descriptor to provide a buffer of *fixed* length for containing, accessing and manipulating data.

Five constructors are available to build a TBuf descriptor and include a default constructor. The content of a TBuf descriptor can be replaced after construction using the assignment operators.

For example, to create a buffer of length 8 initially set to contain the characters "ABC"

```
TBuf<8> str(_L("ABC"));
```

The content of the buffer descriptor can be replaced provided the length of the new data does not exceed the value of the integer template parameter, for example:

```
str = _L("xyz");         // OK
str = _L("rstuvwxyz");   // causes an exception
```

To create a buffer which is intended to contain general binary data, explicitly construct the 8 bit variant TBuf8, for example, to create a 256 byte buffer:

```
TBuf8<256> buf;
...
buf = ...;
```

All the member functions described under the TDesC and TDes classes are available for use by a TBuf descriptor. In summary these are:

Length()	Fetch length of descriptor data.
Size()	Fetch the number of bytes occupied by descriptor data.
Ptr()	Fetch address of descriptor data.
Compare(), CompareF(), CompareC()	Compare data (normally), (folded),(collated).
Match(), MatchF(), MatchC()	Pattern match data (normally), (folded), (collated).
Locate(), LocateF()	Locate a character in forwards direction (normally), (folded).
LocateReverse(), LocateReverseF()	Locate a character in reverse direction (normally), (folded).
Find(), FindF(), FindC	Find data (normally), (folded), (collated).
Left()	Construct TPtrC for leftmost part of data.
Right()	Construct TPtrC for rightmost part of data.
Mid()	Construct TPtrC for portion of data.

Alloc(), AllocL(), AllocLC()	Construct an HBufC for *this* descriptor.
HufEncode()	Huffman encode
HufDecode()	Huffman decode
MaxLength()	Fetch maximum length of descriptor.
MaxSize()	Fetch maximum size of descriptor
SetLength()	Set length of descriptor data
Zero()	Set length of descriptor data to zero
SetMax()	Set length of descriptor data to the maximum value.
Swap()	Swap data between two descriptors.
Copy(), CopyF(), CopyC()	Copy data (normally), (and fold), (and collate).
CopyLC()	Copy data and convert to lower case.
CopyUC()	Copy data and convert to upper case
CopyCP()	Copy data and capitalise
Repeat()	Copy and repeat.
Justify()	Copy and justify.
Insert()	Insert data.
Delete()	Delete data.
Replace()	Replace data.
TrimLeft()	Delete spaces from left side of data area.
TrimRight()	Delete spaces from right side of data area.
Trim()	Delete spaces from both left and right side of data area.
Fold()	Fold characters.
Collate()	Collate characters.
LowerCase()	Convert to lower case.
UpperCase()	Convert to upper case.
Capitalise()	Capitalise.
Fill()	Fill with specified character.
FillZ()	Fill with 0x00.
Num()	Convert numerics to character (hex.digits to lower case).
NumUC()	Convert numerics to (upper case) character.
Format(), FormatList()	Convert multiple arguments to character according to format specification.
Append()	Append data.
AppendFill()	Append with fill characters.
AppendJustify()	Append data and justify
AppendNum()	Append from converted numerics (hex digits to lower case).
AppendNumUC()	Append from converted numerics; convert to uppercase.
AppendFormat(), AppendFormatList()	Append from converted multiple arguments.
ZeroTerminate()	Append zero terminator.
PtrZ()	Append zero terminator and return a pointer.
operators < <= > >= ==	Comparison operators.
operator +=	Appending operator.
operator []	Indexing operator.

Construction

e32.descriptors.TBuf.construction

TBuf() **Default C++ constructor**

TBuf();

Description

The default C++ constructor is used to construct a modifiable buffer descriptor.
The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.

The length of the constructed descriptor is set to zero and the maximum length is set to the value of the integer template parameter <TInt S>.

TBuf() **C++ constructor[with length]**

TBuf(TInt aLength);

Description

The C++ constructor is used to construct the TBuf<S> with the length.

The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.

The length of the constructed descriptor is set to aLength and the maximum length is set to the value of the integer template parameter <TInt S>.

Arguments

TInt aLength	The length of the constructed modifiable buffer descriptor. This value must be non-negative and not greater than the value of the integer template parameter <TInt S> otherwise the constructor will panic with ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRange for the 16 bit variant

---

TBuf() **Copy constructor**

TBuf(const TBuf<S>& aBuf);

Description

The C++ copy constructor constructs a new TBuf<S> object from the existing one.

The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor object.

aBuf's data is copied into the constructed descriptor's data area.

The length of the constructed descriptor is set to the length of aBuf and the maximum length is set to the value of the integer template parameter <TInt S>.

TBuf() **C++ constructor [with any descriptor]**

TBuf(const TDesC& aDes);

Description

The C++ constructor is used to construct the TBuf<S> with any kind of descriptor.

The integer template parameter <TInt S> is used ,by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.

aDes's data is copied into the constructed descriptor's data area.

The length of the constructed descriptor is set to the length of aDes and the maximum length is set to the value of the integer template parameter <TInt S>.

Arguments

const TDesC& aDes	A reference to any type of descriptor used to construct the TBuf<S>.

Notes

The length of aDes must not be greater than the value of the integer template parameter <TInt S> otherwise the constructor will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

TBuf() **C++ constructor [with zero terminated string]**

TBuf(const TText* aString);

Description

The C++ constructor is used to construct the TBuf<S> with a zero terminated string.

The integer template parameter <TInt S> is used, by the compiler, to calculate the size of the data area to be created as part of the constructed descriptor.

The string, excluding the zero terminator, is copied into the constructed descriptor's data area.

The length of the constructed descriptor is set to the length of the string, excluding the zero terminator, and the maximum length is set to the value of the integer template parameter <TInt S>.

Arguments

const TText* aString	The address of the zero terminated string used to construct the TBuf<S>.

Notes

The length of the string, excluding the zero terminator must not be greater than the value of the integer template parameter <TInt S> otherwise the constructor will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

Assignment operators

e32.descriptors.TBuf.assignment-operators

See also e32.descriptors.TDes.assignment-operators.

---

operator = — **Operator = taking a TBuf<S>**

TBuf<S>& operator=(const TBuf<S>& aBuf);

Description

This assignment operator copies the content of the modifiable buffer descriptor aBuf into *this* modifiable buffer descriptor.

aBuf's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aBuf.

Arguments

const TBuf<S>& aBuf	A reference to the modifiable pointer descriptor whose content is to be copied.

Return value

TBuf<S>&	A reference to *this* descriptor.

Operator = — **Operator = taking any descriptor**

TBuf<S>& operator=(const TDesC& aDes);

Description

This assignment operator copies the content of any type of descriptor aDes into *this* modifiable buffer descriptor.

aDes's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TDesc& aDes	A reference to any type of descriptor whose content is to be copied.

Return value

TBuf<S>&	A reference to *this* descriptor.

Notes

The length of aDes must not be greater than the value of the integer template parameter <TInt S> otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

operator = — **Operator = taking a zero terminated string**

TBuf<S>& operator=(const TText* aString);

Description

This assignment operator copies a zero terminated string, excluding the zero terminator, into *this* modifiable buffer descriptor.

The copied string replaces the existing content of *this* descriptor.

The length of *this* descriptor is set to the length of the string, excluding the zero terminator.

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Return value

TBuf<S>&	A reference to *this* descriptor.

Notes

The length of the string, excluding the zero terminator, must not be greater than the value of the template parameter <TInt S> otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

HBufC class — Heap descriptor

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.
TBufCBase	Abstract: implementation convenience.
HBufC	A heap descriptor.

Defined in

e32des8.h for the 8 bit variant (HBufC8).
e32des16.h for the 16 bit variant (HBufC16)

Description

Create an HBufC descriptor to provide a buffer of *fixed* length for containing and accessing data.

The data held in an HBufC descriptor cannot be modified, although it can be replaced using the assignment operators.

The descriptor exists only on the heap but has the important property that it can be resized, i.e. made either larger or smaller, to change the size of its data area. This is achieved by reallocating the descriptor. Unlike the behaviour of dynamic buffers (see e32.dynamic-buffers), reallocation is not done automatically.

An HBufC descriptor is useful in situations where a large fixed length buffer may be required initially but, thereafter, a smaller fixed length buffer is sufficient.

An HBufC descriptor must be constructed using the static member functions New(), NewL() or NewLC() and resized using the ReAlloc() or ReAllocL() member functions. A code fragment illustrates how these might be used:

```
class CAnyClass : CBase
        {
public :
        void AddToBuf(const TDesC& aSrcBuf);
private :
        HBufC* iTgtBuf;
        TInt   iAllocLen;
        }
```

```
void CAnyClass::AddToBuf(const TDesC& aSrcBuf)
    {
    TInt SrcLen = aSrcBuf.Length();

    if (iTgtBuf)
        {
        if (SrcLen > iAllocLen)
            {
            iTgtBuf   = iTgtBuf->ReAllocL(SrcLen);
            iAllocLen = SrcLen;
            }
        }
    else
        {
        iTgtBuf   = HBufC::NewL(SrcLen);
        iAllocLen = SrcLen;
        }

    *iTgtBuf = aSrcBuf;
    }
```

In practice, the use of ReAlloc() here is a little inefficient as the data in the HBufC descriptor is saved across the re-allocation but is then discarded when the content of aSrcBuf is assigned to it.

All the member functions described under the TDesC class are available for use by a TBufC descriptor. In summary these are:

Length()	Fetch length of descriptor data.
Size()	Fetch the number of bytes occupied by descriptor data.
Ptr()	Fetch address of descriptor data.
Compare(), CompareF(), CompareC()	Compare data (normally), (folded),(collated).
Match(),MatchF(),MatchC()	Pattern match data (normally), (folded), (collated).
Locate(),LocateF()	Locate a character in forwards direction (normally), (folded).
LocateReverse(), LocateReverseF()	Locate a character in reverse direction (normally), (folded).
Find(),FindF(),FindC	Find data (normally), (folded), (collated).
Left()	Construct TPtrC for leftmost part of data.
Right()	Construct TPtrC for rightmost part of data.
Mid()	Construct TPtrC for portion of data.
Alloc(),AllocL(),AllocLC()	Construct an HBufC for *this* descriptor.
HufEncode()	Huffman encode
HufDecode()	Huffman decode
operators < <= > >= ==	Comparison operators
operator []	Indexing operator

Allocation and construction

e32.descriptors.HBufC.allocation-and-construction

New(), NewL(), NewLC() — **Create new HBufC**

e32.descriptors.new

static HBufC* New(TInt aMaxLength);
static HBufC* NewL(TInt aMaxLength);
static HBufC* NewLC(TInt aMaxLength);

Description

Use these functions to construct a new HBufC descriptor on the heap.

The functions attempt to acquire a single cell large enough to hold an HBufC object containing a data area with a length which is *at least* aMaxLength. The resulting length of the data area *may* be larger than aMaxLength, depending on the way memory allocation is implemented, but is guaranteed to be *not less* than aMaxLength.

If there is insufficient memory available to create the descriptor, New() returns NULL but both NewL() and NewLC() leave. See e32.exception.intro for more information on leave processing.

If the new descriptor is successfully constructed, NewLC() will place the descriptor on the clean-up stack before returning with the address of that descriptor. See e32.exception.transient for more information on the clean-up stack.

The length of the new descriptor is set to zero.

Use operator= to assign data into the descriptor.

See example eudeshbc.

Arguments

TInt aMaxLength	The required length of the new descriptor's data area. This value must be non-negative otherwise the function will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for the 16 bit variant.

Return value

HBufC*	The address of the newly created HBufC descriptor. New() returns NULL, if there is insufficient memory. NewL() and NewLC() leave, if there is insufficient memory.

Example

These code fragments illustrate how an HBufC descriptor can be constructed.

Use of New():

```
HBufC* ptr;
...
ptr = HBufC::New(64); // buffer length is 64
if (!ptr)
   {
      ...          // could not create the descriptor
   }
```

Use of NewL():

```
ptr = HBufC::NewL(64);
...          // if control returns, allocation is OK
...          // and ptr has sensible value
```

NewL(), NewLC() — Create new HBufC from a stream

e32.descriptors.newfromstream

static HBufC* NewL(RReadStream& aStream,TInt aMaxLength);
static HBufC* NewLC(RReadStream& aStream,TInt aMaxLength);

Description

Use these functions to construct a new HBufC descriptor on the heap and to assign to this new descriptor, data held in the stream aStream.

The functions attempt to acquire a single cell large enough to hold an HBufC object containing a data area whose length is sufficient to contain the data held in the stream. The stream contains both the length of the data and the data itself.

If there is insufficient memory available to create the descriptor or the length value held in the stream is greater then aMaxLength, both NewL() and NewLC() leave. See e32.exception.intro for more information on leave processing.

If the new descriptor is successfully constructed, NewLC() places the descriptor on the clean-up stack before returning with the address of that descriptor. See e32.exception.transient for more information on the clean-up stack.
These functions assume that the stream is currently positioned at an appropriate place, i.e. a point where a descriptor has previously been streamed out (using the operator <<).
See externalizing store.streams.externalizing.descriptors and internalizing store.streams.internalizing.descriptors.
For general information on streams see store.streams-basic and store.streams.
For general information on stores, see store.stores.

Arguments

RReadStream& aStream	The stream from which the length of the new descriptor and the data to be assigned to the new descriptor, are to be taken.
TInt aMaxLength	The maximum permitted length of the new descriptor. The resulting length of the new descriptor must not exceed this value, otherwise the functions leave with a KErrOverflow.

Return value

HBufC*	The address of the newly created HBufC descriptor. Both NewL() and NewLC() leave, if there is insufficient memory or the resulting length exceeds the value of aMaxLength.

NewMax(), NewMaxL(), NewMaxLC() Create new HBufC and set length

static HBufC* NewMax(TInt aMaxLength);
static HBufC* NewMaxL(TInt aMaxLength);
static HBufC* NewMaxLC(TInt aMaxLength);

Description

Use these functions to construct a new HBufC descriptor on the heap.
The functions attempt to acquire a single cell large enough to hold an HBufC object containing a data area with a length which is *at least* aMaxLength. The resulting length of the data area *may* be larger than aMaxLength, depending on the way memory allocation is implemented, but is guaranteed to be *not less* than aMaxLength.
If there is insufficient memory available to create the descriptor, NewMax() returns NULL but both NewMaxL() and NewMaxLC() leave. See e32.exception.intro for more information on leave processing.
If the new descriptor is successfully constructed, NewMaxLC() will place the descriptor on the clean-up stack before returning with the address of that descriptor. See e32.exception.transient for more information on the clean-up stack.
The length of the new descriptor is set to the value of aMaxLength.
Use operator= to assign data into the descriptor.

Arguments

TInt aMaxLength	The required length of the new descriptor's data area and the length given to the descriptor. This value must be non-negative otherwise the function will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for the 16 bit variant.

Return value

HBufC*	The address of the newly created HBufC descriptor. NewMax() returns NULL, if there is insufficient memory. NewMaxL() and NewMaxLC() leave, if there is insufficient memory.

Example

See e32.descriptors.new for an example

Re-allocation

e32.descriptors.HBufC.reallocation

ReAlloc(), ReAllocL() **Expand/contract the HBufC buffer**

HBufC* ReAlloc(TInt aMaxLength);
HBufC* ReAllocL(TInt aMaxLength);

Description

Use this function to expand or contract the data area of an existing HBufC descriptor. This is done by:

- constructing a new HBufC descriptor on the heap containing a data area of length aMaxLength
- copying the contents of the original descriptor into the new descriptor
- deleting the original descriptor

The functions attempt to acquire a single cell large enough to hold an HBufC object containing a data area of length aMaxLength.

If there is insufficient memory available to construct the new descriptor, ReAlloc() returns NULL but ReAllocL() leaves. In either case the original descriptor remains unchanged; see e32.exception.intro for more information on leave processing.

If the new descriptor is successfully constructed, then the content of the original descriptor is copied into the new descriptor, the original descriptor is deleted and the address of the new descriptor is returned to the caller. The length of the re-allocated descriptor remains unchanged.

Arguments

TInt aMaxLength	The new length of the descriptor's data area. This value must be non-negative otherwise the function will panic with ETDes8MaxLengthNegative for the 8 bit variant or ETDes16MaxLengthNegative for the 16 bit variant This value must not be less than the length of the data in the original descriptor otherwise the function will panic with ETDes8ReAllocTooSmall for the 8 bit variant or ETDes16ReAllocTooSmall for the 8 bit variant

Return value

HBufC*	The address of the expanded or contracted HBufC descriptor. ReAlloc() returns NULL, if there is insufficient memory. ReAllocL() leaves, if there is insufficient memory.

Notes

If re-allocation is successful, be aware that any pointers containing the address of the original HBufC descriptor are no longer valid. This also applies to the cleanup stack; care must be taken in the design and implementation of code when a pointer to an HBufC descriptor is placed on the cleanup stack and the descriptor is subsequently re-allocated.

Take particular care if using the Des() member function to create a TPtr descriptor. A TPtr descriptor created before re-allocating the HBufC descriptor, is not guaranteed to have a valid pointer after re-allocation. Any attempt to modify data using the TPtr after re-allocation may have undefined consequences.

Example

These code fragments illustrate how ReAlloc() can work.

```
HBufC* old;
HBufC* newgood;
HBufC* newbad;
...
old   = HBufC::NewL(16);   // buffer length is 16
*old  = _L("abcdefghijkl"); // descriptor length is 12
...
newgood = old->ReAllocL(24);   // first reallocation OK
newbad  = newgood->ReAllocL(8); // second reallocation panics
```

After the first reallocation, newgood points to the re-allocated descriptor, old contains an invalid address. The second re-allocation panics because an attempt is being made to contract the data area to a length of 8 which is smaller than the original length of the descriptor.

Create a modifiable pointer descriptor

e32.descriptors.HBufC.create-TPtr

Des() — **Create & return a TPtr**

TPtr Des();

Description

Use this function to construct and return a modifiable pointer descriptor to represent *this* descriptor.

The content of a HBufC descriptor cannot be altered but creating a modifiable pointer descriptor provides a mechanism for modifying that data.

The length of the new TPtr is set to the length of *this* descriptor.

The maximum length of the new TPtr is set to the length of *this* descriptor's data area.

The new TPtr is set to point to *this* descriptor. *This* descriptor's data is neither copied nor moved.

This descriptor's data can be modified through the newly constructed TPtr. If there is any change to the length of the data, then the length of both *this* descriptor and the TPtr is modified to reflect that change.

Return value

TPtr	A modifiable pointer descriptor representing *this* HBufC descriptor.

Notes

Take particular care if using ReAlloc() or ReallocL(). A TPtr descriptor created before re-allocating the HBufC descriptor, is not guaranteed to have a valid pointer after re-allocation. Any attempt to modify data using the TPtr after re-allocation may have undefined consequences.

Assignment operators

e32.descriptors.HBufC.assignment-operators

See also e32.descriptors.TDes.assignment-operators.

operator = — **Operator = taking HBufC descriptor**

HBufC& operator=(const HBufC& aLcb);

Description

This assignment operator copies the content of the heap descriptor aLcb into *this* heap descriptor.

aLcb's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aLcb.

Arguments

const HBufC& aLcb	A reference to the heap descriptor whose content is to be copied.

Return value

HBufC&	A reference to *this* descriptor.

Notes

The length of the descriptor aLcb must not be greater than the length of *this* descriptor's data area otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

Operator = — Operator = taking any descriptor

HBufC& operator=(const TDesC& aDes);

Description

This assignment operator copies the content of any type of descriptor aDes into *this* heap descriptor.

aDes's data is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be copied.

Return value

HBUfC&	A reference to *this* descriptor.

Notes

The length of the descriptor aDes must not be greater than the length of *this* descriptor's data area otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

operator = — Operator = taking zero terminated string

HBufC& operator=(const TText* aString);

Description

This assignment operator copies a zero terminated string, excluding the zero terminator, into *this* heap descriptor.

The string, excluding the zero terminator, is copied into *this* descriptor's data area, replacing the existing content. The length of *this* descriptor is set to the length of the string, excluding the zero terminator.

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Return value

HBufC&	A reference to *this* descriptor.

Notes

The length of the string, excluding the zero terminator, must not be greater than the length of *this* descriptor's data area otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

TDesC class

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.

Defined in

e32des8.h for the 8 bit variant (TDesC8).

e32des16.h for the 16 bit variant (TDesC16)

Description

The class is abstract and cannot be constructed. It implements that aspect of descriptor behaviour which does not modify the descriptor's data.

All member functions described here are available to all derived descriptor classes.

Basic information

e32.descriptors.TDesC.basic-functions

Length() **Fetch descriptor length**

TInt Length() const;

Description

Use this member function to return the number of data items in the descriptor's data area.
For 8 bit descriptors, data is single-byte valued and the length has the same value as the number of bytes occupied by that data. For 16 bit descriptors, data is double-byte valued and the length value is half the number of bytes occupied by that data.
For example, if a descriptor data area contains one ASCII text character, the returned length is one and it occupies one byte (and the Size() function returns one); if a data area contains one UNICODE text character, the returned length is also one but it occupies two bytes (and the Size() function returns two).

Return value

TInt	The length of the data within the data area.

Size() **Fetch the number of bytes occupied by data**

TInt Size() const;

Use this member function to return the number of bytes occupied by data in the descriptor's data area. For 8 bit descriptors, this value is the same as the length of the data. For 16 bit descriptors, this value is twice the length of the data.

Return value

TInt	The number of bytes occupied by data within the descriptor's data area.

Ptr() **Fetch address of descriptor's data area**

const TUint??* Ptr() const;

Description

Use this member function to return the address of the descriptor's data area. The address *cannot* be used to change the descriptor's data.

Return Value

const TUint??*	The address of the data area. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.

Notes

If the descriptor is used for strings, then the pointer can be regarded as a TText type and there is no need to distinguish between the 8 bit and 16 bit variants. If the descriptor is used for binary data then the pointer should be regarded as a TUint8 type.

Comparison

e32.descriptors.TDesC.comparison

Compare(), CompareF(), CompareC() **Compare data**

TInt Compare(const TDesC& aDes) const;
TInt CompareF(const TDesC& aDes) const;
TInt CompareC(const TDesC& aDes) const;

Description

Use these functions to compare the content of *this* descriptor with the content of the descriptor aDes.
The comparison proceeds on a byte for byte basis in the 8 bit variant and on a double-byte for double-byte basis in the 16 bit variant.
The result of the comparison is based on the difference of the first bytes (or double-bytes) to disagree. Two descriptors are equal if they have the same length and content. Where two descriptors have different lengths and the shorter matches the first part of the longer, the shorter is considered to be less than the longer.

CompareF() takes the folded content of both descriptors for comparison while CompareC() takes the collated content of both descriptors for comparison. Compare() simply takes the content of both descriptors as they stand.

See e32.descriptors.folding for more information on folding and e32.descriptors.collating for more information on collating.

Compare() is useful for comparing both text and binary data. CompareF() is useful for making case-insensitive text comparisons.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be compared with *this* descriptor's content.

Return value

TInt	Positive, if *this* descriptor is greater than aDes. Negative, if *this* descriptor is less than aDes. Zero, if both descriptors have the same length *and* the their contents are the same.

Example

This code fragment illustrates the use of Compare().

```
TBufC<8> str(_L("abcd"));
...
str.Compare(_L("abcde")); // returns -ve
str.Compare(_L("abc"));   // returns +ve
str.Compare(_L("abcd"));  // returns zero
str.Compare(_L("abcx"));  // returns -ve
```

Thus:

- "abcd" is less than "abcde".
- "abcd" is greater than "abc".
- "abcd" is equal to "abcd".
- "abcd" is less than "abcx".

Pattern matching

e32.descriptors.TDesC.pattern-matching

Match(), MatchF(), MatchC() — Pattern match data

TInt Match(const TDesC& aDes) const;
TInt MatchF(const TDesC& aDes) const;
TInt MatchC(const TDesC& aDes) const;

Description

Use these functions to compare the match pattern in aDes's data area against the content of *this* descriptor.

The match pattern can contain the wildcard characters '*' and '?', where '*' matches zero or more consecutive occurrences of any character and '?' matches a single occurrence of any character.

MatchF() takes the folded content of both descriptors for matching while MatchC() takes the collated content of both descriptors for matching. Match() simply takes the content of both descriptors as they stand.

See e32.descriptors.folding for more information on folding and e32.descriptors.collating for more information on collating.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose data area contains the match pattern.

Return value

TInt — If the content of *this* descriptor matches the pattern supplied in aDes's data area, then this is the length of the most significant portion (i.e. the leftmost part) of *this* data area which matches the pattern.
If the content of *this* descriptor does not match the pattern supplied in aDes, KNotFound is returned.

Notes

To test for the existence of a pattern *within* a text string, the pattern must start and end with an '*'.
If the pattern terminates with an '*' wildcard character and the supplied string matches the pattern, then the value returned is the length of the string which matches the pattern up to but not including the final asterisk. This is illustrated in the examples below.

Example

This code fragment illustrates the use of Match()

```
...
TBufC<32> str(_L("abcdefghijklmnopqrstuvwxyz"));
...
str.Match(_L("*ijk*"));    //returns -> 11
str.Match(_L("*i?k*"));    //        -> 11
str.Match(_L("ijk*"));     //        -> KNotFound
str.Match(_L("abcd"));     //        -> KNotFound
str.Match(_L("*i*mn*"));   //        -> 14
str.Match(_L("abcdef*"));  //        -> 6
str.Match(_L("*"));        //        -> 0
```

Locate a character

e32.descriptors.TDesC.locate-character

Locate(), LocateF() — Locate a character forwards

TInt Locate(TChar aChar) const;
TInt LocateF(TChar aChar) const;

Description

Use these functions to find the first occurrence of a character within *this* descriptor. The search starts at the beginning (i.e. the left side) of the data area.
LocateF() takes the folded content of the descriptor and folds the supplied character before searching. This is useful in searching for a character in a case-insensitive manner.
See e32.descriptors.folding for more information on folding.

Arguments

TChar aChar — The character to be found.

Return value

TInt — If the character is found, this is the offset of its position from the *beginning* of the data area.
KNotFound is returned if the character is not found.

Example

This code fragment illustrates the use of Locate().

```
...
TBufC<8> str(_L("abcd"));
...
str.Locate('d');  // returns 3
str.Locate('a');  // returns 0
str.Locate('b');  // returns 1
str.Locate('x');  // returns KNotFound
...
```

LocateReverse(), LocateReverseF() — Locate a character in reverse

TInt LocateReverse(TChar aChar) const;
TInt LocateReverseF(TChar aChar) const;

Description

Use these functions to find the first occurrence of a character within *this* descriptor, searching from the back (i.e. the right side) of the data area.
LocateReverseF() takes the folded content of the descriptor and folds the supplied character before searching. This is useful in searching for a character in a case-insensitive manner.
See e32.descriptors.folding for more information on folding.

Arguments

TChar aChar	The character to be found.

Return value

TInt	If the character is found, this is the offset of its position from *beginning* of data area. KNotFound is returned if the character is not found.

Find data

e32.descriptors.TDesC.find-data

Find(), FindF(), FindC() — Find data (given by descriptor)

TInt Find(const TDesC& aDes) const;
TInt FindF(const TDesC &aDes) const;
TInt FindC(const TDesC &aDes) const;

Description

Use these functions to find the location, within *this* descriptor, of the data supplied in aDes's. The search starts at the beginning (i.e. the left side) of *this* descriptor's data area.
FindF() folds the content of both descriptors for the purposes of searching while FindC() collates the content. See e32.descriptors.folding for more information on folding and e32.descriptors.collating for more information on collating.
While these functions are most useful in searching for the existence and location of a sub-string within a string, they can, nevertheless, be used on general binary data.
FindF() is useful in performing a case-independent search of a string for a sub-string; FindC() is useful in searching a string for a sub-string on the basis of their collating sequence.

Arguments

const TDesC& aDes	A reference to any type of descriptor which contains the data sequence to be found within *this* descriptor.

Return value

TInt	If the data is found, the offset of the starting position of the data from the *beginning* of this descriptor's data area. KNotFound is returned if the data is not found.

Notes

If the descriptor aDes has zero length, then the returned value will be zero.

Example

This code fragment illustrates the use of Find().

```
...
TBufC<32> str(_L("abcdefghijklmnopqrstuvwxyz"));
...
str.Find(_L("abc"));                 // returns 0
str.Find(_L("bcde"));                // returns 1
str.Find(_L("uvwxyz"));              // returns 20
str.Find(_L("0123"));                // returns KNotFound
str.FInd(_L("abcdefghijklmnopqrstuvwxyz01")); // returns KNotFound
str.Find(_L(""));                    // returns 0
...
```

Find(), FindF(), FindC() **Find data (given by address and length)**

TInt Find(const TUint??* aBuf,TInt aLen) const;
TInt FindF(const TUint??* aBuf,TInt aLen) const;
TInt FindC(const TUint??* aBuf,TInt aLen) const;

Description

Use these functions to find the location, within *this* descriptor, of the data of length aLen at address aBuf. The search starts at the beginning (i.e. the left side) of *this* descriptor's data area.

FindF() folds the content of both *this* descriptor and the data at aBuf for the purposes of searching, while FindC() collates the content. See e32.descriptors.folding for more information on folding and e32.descriptors.collating for more information on collating.

While these functions are most useful in searching for the existence and location of a sub-string within a string, they can, nevertheless, be used on general binary data.

FindF() is useful in performing a case-independent search of a string for a sub-string; FindC() is useful in searching a string for a sub-string on the basis of their collating sequence.

Arguments

const TUint??* aBuf	The address of the data sequence to be found within *this* descriptor. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLen	The length of the data sequence. This value must be non-negative otherwise the function will panic with ETDes8LengthNegative for the 8 bit variant or ETDes16LengthNegative for the 16 bit variant.

Return value

TInt	If the data is found, the offset of the starting position of the data from the *beginning* of this descriptor's data area. KNotFound is returned if the data is not found.

Notes

If aLen is zero, then the returned value will be zero.

Extraction

e32.descriptors.TDesC.extraction

Left() **Construct TPtrC for leftmost part of data**

TPtrC Left(TInt aLength) const;

Description

Use this function to construct and return a constant pointer descriptor to represent the leftmost part of *this* descriptor's data.

Arguments

TInt aLength	The length of data within *this* descriptor which the new descriptor is to represent. This value must not be negative and must not be greater than the current length of *this* descriptor otherwise the function will panic with ETDes8PosOutOfRange for the 8 bit variant or ETDes16PosOutOfRange for the 16 bit variant.

Return value

TPtrC	The constant pointer descriptor representing the leftmost part of *this* descriptor's data area.

Notes

No movement or copying of data takes place; the data represented by the returned descriptor occupies the same memory as the original.

Specifying a zero value for aLength will result in a descriptor which represents no data.

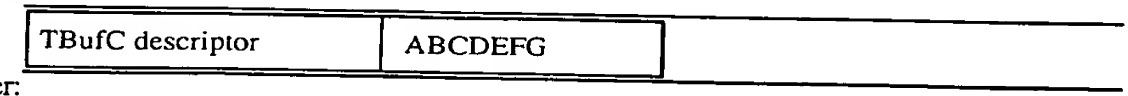
Example

The code fragments illustrate the use of Left().

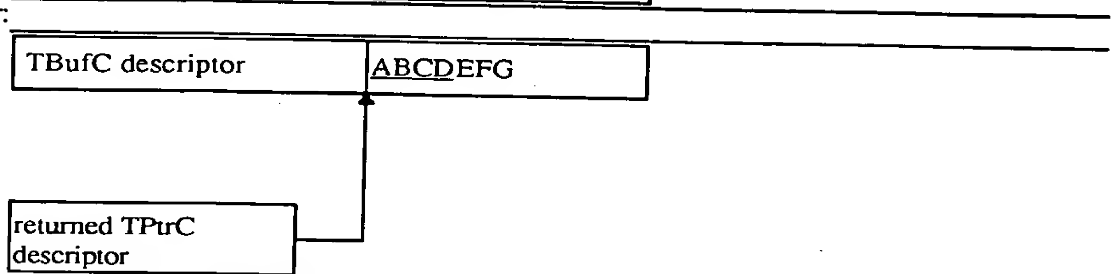
```
...
TBufC<8> str(_L("abcdefg"));
...                          // returns a TPtrC descriptor
str.Left(4);                    // representing the string
...                          // "abcd"
```

The result of this specific example can be visualised in a before and after fashion. The underlined text in the "after" diagram indicates the data represented by the returned descriptor.

Before:



After:



Note that the result of the following calls to Left() will result in a panic.

```
...
TBufC<8> str(_L("abcdefg"));
...
str.Left(8);              // panic !!
str.Left(-1);             // panic !!
...
```

Right() — Construct TPtrC for rightmost part of data

TPtrC Right(TInt aLength) const;

Description

Use this function to create and return a constant pointer descriptor to represent the rightmost part of *this* descriptor's data.

Arguments

TInt aLength	The length of data within *this* descriptor which the new descriptor is to represent. This value must not be negative and must not be greater than the current length of *this* descriptor otherwise the function will panic with ETDes8PosOutOfRange for the 8 bit variant or ETDes16PosOutOfRange for the 16 bit variant.

Return value

TPtrC	The constant pointer descriptor representing the rightmost part of *this* descriptor's data area.

Notes

No movement or copying of data takes place; the data represented by the returned descriptor occupies the same memory as the original.

Specifying a zero value for aLength will result in a descriptor which represents no data.

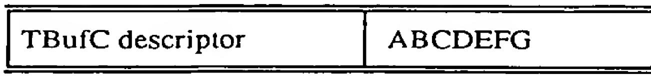
Example

The code fragments illustrate the use of Right().

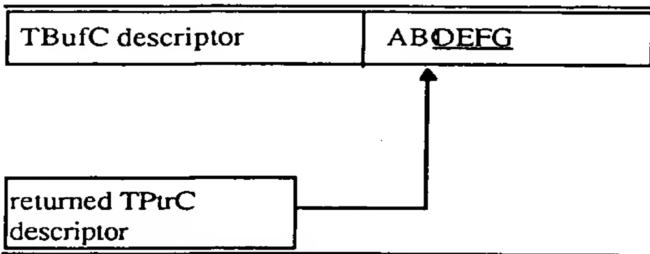
```
...
TBufC<8> str(_L("abcdefg"));
...                          // returns a TPtrC descriptor
str.Right(4);                   // representing the string
...                          // "defg"
```

The result of this specific example can be visualised in a before and after fashion. The underlined text in the "after" diagram indicates the data represented by the returned descriptor.

Before:



After:



Note that the result of the following calls to Right() will result in a panic.

```
...
TBufC<8> str(_L("abcdefg"));
...
str.Right(8);          // panic !!
str.Right(-1);         // panic !!
...
```

Mid() — Construct TPtrC for portion of data

TPtrC Mid(TInt aPos) const;

TPtrC Mid(TInt aPos,TInt aLength) const;

Description

Use these functions to create and return a constant pointer descriptor to represent a portion of the data held in *this* descriptor.

The portion can be identified either by position alone or by position and length. If identified by position alone, the implied length is the length of data from the specified position to the end of the data in *this* descriptor.

Arguments

TInt aPos	The starting position, within *this* descriptor, of the data to be represented by the new constant descriptor. The position is given relative to zero; i.e. a zero value implies the leftmost data position. This value is subject to the constraints outlined below.
TInt aLength	The length of data which the new descriptor is to represent. This value is subject to the constraints outlined below.

If aPos alone is specified, then 0 <= aPos <= length of *this* descriptor.

If aPos and aLength are specified, then 0 <= (aPos + aLength) <= length of *this* descriptor.

If these limits are exceeded, then the functions will panic with ETDes8PosOutOfRange for the 8 bit variant or ETDes16PosOutOfRange for the 16 bit variant.

Return value

TPtrC	The constant pointer descriptor representing the selected portion of *this* descriptor's data.

Notes

No movement or copying of data takes place; the data represented by the returned descriptor occupies the same memory as the original.

Specifying a value of aPos which has the same value as the length of the data, will result in a constant pointer descriptor which represents no data.

Example

The code fragments illustrate the use of Mid().

```
...
TBufC str(_L("abcdefg"));
...                          // returns TPtrC descriptors
                             // representing the strings...

str.Mid(0);                  //"abcdefg"
str.Mid(1);                  //"bcdefg"
str.Mid(6);                  //"g"
str.Mid(3,3);                //"def"
str.Mid(0,7);                //"abcdefg"
...
str.Mid(8);                  // Panics !!
str.Mid(3,5);                // Panics!!
...
```

Create a heap descriptor (HBufC)

e32.descriptors.TDesC.create-HBufC

Alloc(), AllocL(), AllocLC() — **Create new HBufC for *this* descriptor**

HBufC* Alloc() const;

HBufC* AllocL() const;

HBufC* AllocLC() const;

Description

Use these functions to allocate and construct a new HBufC descriptor on the heap and initialise it using the content of *this* descriptor.

The functions attempt to acquire a single cell large enough to hold an HBufC object containing a data area whose length is the same as the current length of *this* descriptor. The content of *this* descriptor is copied into the new HBufC descriptor.

If there is insufficient memory available to create the new HBufC descriptor, Alloc() returns NULL but both AllocL() and AllocLC() leave. See e32.exception.intro for more information on leave processing.

If the new descriptor is successfully created, AllocLC() will place the new descriptor on the clean-up stack before returning with the address of that descriptor. See e32.exception.transient for more information on the clean-up stack.

Return value

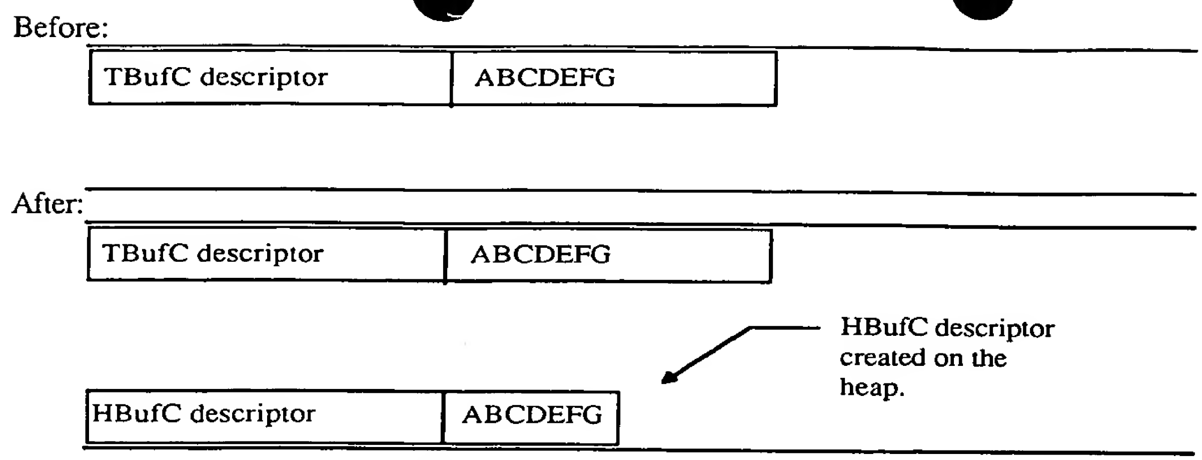
HBufC* — The address of the newly created HBufC descriptor.
Alloc() returns NULL, if there is insufficient memory.
AllocL() and AllocLC() leave, if there is insufficient memory.

Example

The code fragments illustrate the use of AllocL().

```
...
TBufC<16> str(_L("abcdefg"));
HBufC*   ptr;
...
ptr = str.AllocL();   // Returns address of new HBufC descriptor
...                   // holding the string "abcdefg".
ptr.Length();         // Returns the length 7
...
```

The result of this specific example can be visualised in a before and after fashion.



Huffman Encoding/Decoding

e32.descriptors.TDesC.huffman-encoding-decoding

HufEncode()

Huffman encode

TInt HufEncode(TDes& aDest) const;
TInt HufEncode(TDes& aDest,const TUint8* aHufBits) const;

Description

Use this function to Huffman encode the data in *this* descriptor and place the result into the descriptor aDest. The target descriptor must be a modifiable type; i.e. either a TPtr or TBuf. The caller can supply a Huffman tree or use the built-in tree.

Arguments

TDes& aDest	A reference to the modifiable descriptor which is to hold the result of encoding the data in *this* descriptor.
const TUint8* aHufBits	If specified, the Huffman tree to be used for encoding. This is of type TUint8* for both 8 bit and 16 bit descriptors. If not supplied, the built-in Huffman tree is used.

Return value

TInt	The total number of bits occupied by the encoded data.

HufDecode()

Huffman decode

void HufDecode(TDes &aDest) const;
void HufDecode(TDes &aDest,const TUint8 *aHufTree) const;

Description

Use this function to Huffman decode the data in *this* descriptor and place the result into the descriptor aDest. The target descriptor must be a modifiable type; i.e. either a TPtr or TBuf. The caller can supply a Huffman tree or use the built-in tree.

Arguments

TDes& aDest	A reference to the descriptor which is to hold the result of decoding the data in *this* descriptor.
const TUint8* aHufBits	If specified, the Huffman tree to be used for decoding. This is of type TUint8* for both 8 bit and 16 bit descriptors. If not supplied, the built-in Huffman tree is used.

Comparison operators

e32.descriptors.TDesC.comparison-operators

operators < <= > >= == !=Comparison operators taking any descriptor

```
TInt operator<(const TDesC& aDes) const;
TInt operator<=(const TDesC& aDes) const;
TInt operator>(const TDesC& aDes) const;
TInt operator>=(const TDesC& aDes) const;
TInt operator==(const TDesC& aDes) const;
TInt operator!=(const TDesC& aDes) const;
```

Description

Use these operators to determine whether the content of *this* descriptor is:

- less than
- less than or equal to
- greater than
- greater than or equal to
- equal to
- not equal to

the content of aDes.

The comparison is implemented using the TDesC::Compare() member function. See this member function for more detail on the comparison process.

Arguments

const TDesC& aDes	A reference to the descriptor whose content is to be compared with the content of *this* descriptor.

Return value

TInt	true or false

Example

This code fragment illustrates the use of Compare().

```
TBufC<8> str(_L("abcd"));
...
if (str == _L("abcde")) // returns false
  {
  ...
  }

if (str < _L("abcx"))  // returns true
  {
  ...
  }

if (str > _L("abc"))  // returns true
  {
  ...
  }
```

Indexing operator

e32.descriptors.TDesC.indexing-operator

operator [] operator []

```
const TUint??& operator[](TInt anIndex) const;
```

Description

Use this operator to return a reference to a single data item within *this* descriptor (e.g. a text character). The data can be considered as an array of ASCII or UNICODE characters or as an array of bytes (or double-bytes) of binary data.

This operator allows the individual elements of the array to be accessed but *not changed.*

Arguments

TInt anIndex — The index value indicating the position of the element within the data area. The index is given relative to zero; i.e. zero implies the leftmost data position.
This value must be non-negative *and* less than the current length of the descriptor otherwise the operation will panic with ETDes8IndexOutOfRange for the 8 bit variant or ETDes16IndexOutOfRange for the 16 bit variant

Return value

const TUint??& — A reference to the data at position anIndex. The data is of type TUint8& for 8 bit variants and of type TUint16& for 16 bit variants.

Example

The code fragments illustrates the use of operator[].

```
TBufC<8> str(_L("abcdefg"));
...
str[0];             // returns reference to 'a'
str[3];             // returns reference to 'd'
str[7];             // Panics !!
if (str[0] == 'a')     // ...compare returns True
    {
    ...
    }
if (str[6] == 'x')     // ...compare returns False
    {
    ...
    }
```

TDes class

Overview

Derivation

TDesC	Abstract: implements descriptor behaviour which does not modify data.
TDes	Abstract: implements descriptor behaviour which can change data.

Defined in

e32des8.h for the 8 bit variant (TDes8).

e32des16.h for the 16 bit variant (TDes16)

Description

The class is abstract and cannot be constructed. It implements that aspect of descriptor behaviour which modifies the descriptor's data.
All member functions described here are available to all derived descriptor classes.

Basic functions

e32.descriptors.TDes.basic-functions

MaxLength() — Fetch maximum length of descriptor

TInt MaxLength() const;

Description

Use this function to return the maximum length of data that the descriptor's data area can hold.
For modifiable descriptors, the amount of data that a descriptor's data area can hold is variable; however, there is an upper limit and this limit is the value returned by the function.
For 8 bit descriptors, data is single-byte valued and the maximum length has the same value as the maximum size. For 16 bit descriptors, data is double-byte valued and the value of the maximum length is half the maximum size.

Return value

TInt The maximum length of data that the descriptor's data area can hold.

MaxSize() **Fetch maximum size of descriptor**

TInt MaxSize() const;

Description

Use this function to fetch the maximum size of the descriptor's data area, in bytes.
For 8 bit descriptors, data is single-byte and the maximum size is the same value as the maximum length.
For 16 bit descriptors, data is double-byte and the maximum size is twice the value of the maximum length.

Return value

TInt The maximum size of the descriptor's data area.

Change length

e32.descriptors.TDes.change-length

SetLength() **Set length of data**

void SetLength(TInt aLength);

Description

Use this function to set the length of the descriptor to the value of aLength.

Arguments

TInt aLength The new length of the descriptor.
This value must be non-negative and must not be greater than the maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

Zero() **Set length of data to zero**

void Zero();

Description

Use this function to set the length of the descriptor to zero.

SetMax() **Set length of data to maximum**

void SetMax();

Description

Use this function to set the length of the descriptor to its maximum value.

Swap

e32.descriptors.TDes.swap

Swap() **Swap descriptor contents**

void Swap(TDes& aDes);

Description

Swap the contents of *this* descriptor with the contents of aDes. The lengths of both descriptors are also swapped to reflect the change of data.

Arguments

TDes& aDes A reference to the descriptor whose contents are to be swapped with the contents *this* descriptor. This descriptor must be a modifiable type; i.e. either a TPtr or TB

Notes

Each descriptor must be capable of accommodating the contents of the other descriptor. If the maximum length of a descriptor is smaller than the length of the other descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

Example

The following code fragment illustrates the use of Swap()

```
...
TBuf<8> buf1(_L("abcde"));
TBuf<8> buf2(_L("xyz"));
TBuf<16> buf3(_L("0123456789"));
...
buf1.Swap(buf2);   // contents of buf1 and buf2 swapped OK
buf1.Swap(buf3);   // Panic !!
...
```

Copy

e32.descriptors.TDes.copy

Copy() **Copy (unmodified) from any 8 bit or 16 bit descriptor**

void Copy(const TDesC8& aDes);
void Copy(const TDesC16& aDes);

Description

Use these functions to copy the content of any descriptor aDes into *this* descriptor. The copied data replaces the existing content of *this* descriptor.
The length of *this* descriptor is set to the length of aDes.
If *this* descriptor is the 8 bit variant, Copy() is overloaded so that it can take another 8 bit descriptor or a 16 bit descriptor as source.
If *this* descriptor is the 16 bit variant, Copy() is overloaded so that it can take an 8 bit descriptor or another 16 bit descriptor as source.
Thus:

- an 8 bit descriptor can be copied to an 8 bit descriptor
- an 8 bit descriptor can be copied to a 16 bit descriptor
- a 16 bit descriptor can be copied to an 8 bit descriptor
- a 16 bit descriptor can be copied to a 16 bit descriptor

In the case where a 16 bit descriptor is copied to an 8 bit descriptor, each double-byte is copied into the corresponding single byte where the value of the double-byte is less than decimal 256. A double-byte value of 256 or greater cannot be copied and the corresponding single byte is set to a value of decimal 1.
In practice, the most common situation is to copy either 8 bit to 8 bit or 16 bit to 16 bit.

Arguments

const TDesC8& aDes *or* const TDesC16& aDes	A reference to any type of descriptor whose content is to be copied into *this* descriptor.

Notes

The length of the data in aDes cannot be greater than the maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Example

The code fragment illustrates the use of Copy().

```
...
TBuf<8> str;
...
str.Copy(_L"abcdefg");      // copies "abcdefg" to tmp
str.Length();               // returns 7
str.MaxLength();            // returns 8
...
str.Copy(_L"abc");          // copies "abc" to tmp
str.Length();               // returns 3
str.MaxLength();            // returns 8
...
str.Copy(_L"abcdefghi");    // Panics !!
```

Copy() — **Copy from zero terminated string**

void Copy(const TText* aString);

Description

Use this function to copy a zero terminated string, excluding the zero terminator, into *this* descriptor replacing the existing content.
The length of *this* descriptor is set to the length of the string, excluding the zero terminator.

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Notes

The length of the string, excluding the zero terminator, must not be greater than the maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Copy() — **Copy from address**

void Copy(const TUint??* aBuf,TInt aLength);

Description

Use this function to copy data of length aLength from the memory location aBuf.
The length of *this* descriptor is set to the value of aLength.

Arguments

const TUint??* aBuf	The address of the data to be copied. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLength	The length of the data to be copied. This value must be non-negative and must not be greater than maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

CopyF(), CopyC() — **Copy (and fold/collate) from any descriptor**

void CopyF(const TDesC& aDes);
void CopyC(const TDesC& aDes);

Description

Use these functions to copy the content of aDesC into *this* descriptor, replacing the existing content.
The length of *this* descriptor is set to the length of aDes.
CopyF() folds the data before insertion into *this* descriptor and CopyC() collates the data before insertion.. See e32.descriptors.folding for more information on folding and e32.descriptors.collating for more information on collating.
These functions are only of practical use for text data.

Arguments

const TDesC& aDes — A reference to the descriptor whose content is to be copied into *this* descriptor.

Notes

The length of the data in aDes must not be greater than the maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

CopyLC(), CopyUC(), CopyCP() Copy (and change case) from any descriptor

void CopyLC(const TDesC& aDes);
void CopyUC(const TDesC& aDes);
void CopyCP(const TDesC& aDes);

Description

Use these functions to copy the content of aDesC into *this* descriptor, replacing the existing content.

The length of *this* descriptor is set to the length of aDes.

Before copying data , CopyLC() converts characters to lower case, CopyUC()converts characters to upper case and CopyCP() capitalises text.

Capitalisation means the conversion of the first character in a string to upper case and converting all remaining characters to lower case.

Accented characters retain their accents.

These functions are only of practical use for string data.

Arguments

const TDesC& aDes — A reference to any type of descriptor whose content is to be copied into *this* descriptor.

Notes

The length of the data in aDes must not be greater than the maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

Copy repeat

e32.descriptors.TDes.copy-repeat

Repeat() Copy from descriptor and repeat

void Repeat(const TDesC& aDes)

Description

Use this function to copy the content of the descriptor aDes, repeatedly into *this* descriptor. The copies are concatenated together within *this* descriptor and replace any existing data. Copying proceeds until *this* descriptor is filled up to its current length. If it cannot contain a whole number of copies of aDes, then the last copy within *this* descriptor is truncated.

Arguments

const TDes& aDes — A reference to any type of descriptor whose contents are to be repeatedly copie

Example

The following code fragment illustrates the use of Repeat().

```
...
TBuf<8> tgt(8);            // length of tgt is the same as the
                           // maximum which is 8
...
                           // following strings generated in tgt
tgt.Repeat(_L("ab"));      // "abababab"
tgt.Repeat(_L("abc");      // "abcabcab"
tgt.Repeat(_L("abcde"));   // "abcdeabc"
...
```

```
...                         // changing length to 7 has the
                            // following effect
tgt.SetLength(7);
tgt.Repeat(_L("ab"));        // "abababa"
tgt.Repeat(_L("abc"));       // "abcabca"
tgt.Repeat(_L("abcde"));     // "abcdeab"
```

Repeat() **Copy from address and repeat**

void Repeat(const TUint??* aBuf,TInt aLength);

Description

Use this function to copy data of length aLength from the memory location aBuf, repeatedly into *this* descriptor. The copies are concatenated together within *this* descriptor and replace any existing data.

Copying proceeds until *this* descriptor is filled up to its current length. If it cannot contain a whole number of copies, then the last copy within *this* descriptor is truncated.

Arguments

const TUint??* aBuf	The address of the data to be repeatedly copied. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLength	The length of the data to be repeatedly copied. This value must be non-negative otherwise the function will panic with ETDes8LengthNegative for the 8 bit variant or ETDes16LengthNegative for the 16 bit variant.

Copy and justify

e32.descriptors.TDes.copy-justify

Justify() **Copy from descriptor and justify**

e32.descriptors.TDes.copy-justify.justify

void Justify(const TDesC& aDes,TInt aWidth,TAlign anAlignment,TChar aFill);

Description

Use this function to copy the content of aDes into *this* descriptor, replacing the existing content. The target area is considered to be a field of width aWidth positioned at the beginning (i.e. the left hand side) of *this* descriptor's data area. The content of aDes is copied into the target area and aligned within it as dictated by the value of anAlignment.

If aWidth has the value KDefaultJustifyWidth, then the width of the target area (i.e. the value of aWidth) is re-set to the length of aDes.

If the length of aDes is smaller than the width of the target area, then any spare space within the target area is padded with the fill character aFill.

If the length of aDes is greater than the width of the target area, then the amount of data copied from aDes is limited to the value of aWidth.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be copied.
TInt aWidth	The width of the target area. This must be one of: • KDefaultJustifyWidth • a non-negative value If it has the value KDefaultJustifyWidth, then it is re-set to the length of aDes. If the value is less than the length of aDes, then the amount of data copied from aDes into the target area is limited to aWidth.
TAlign anAlignment	An enumeration which dictates the alignment of the data within the target area. See e32.enum.TAlign.
TChar aFill	The fill character used to pad the target area.

Notes

If the width of the target area is greater than the maximum length of *this* descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

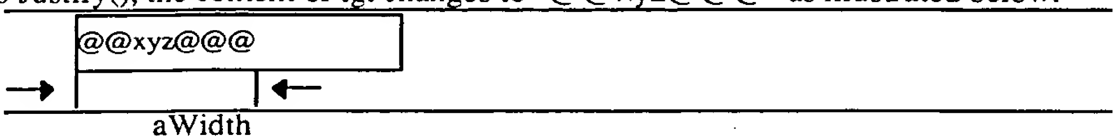
Do not set aWidth to a negative value (other than KDefaultJustifyWidth) as this may have unpredictable consequences.

Example

The following code fragments illustrate the use of Justify().

```
...
TBuf<16> tgt(_L("abc"));
...
tgt.Justify(_L("xyz"),8,ECenter,'@');
```

The descriptor tgt has a maximum length of 16 and initially holds the string "abc". After the call to Justify(), the content of tgt changes to "@@xyz@@@" as illustrated below.



In this example, the content of the source descriptor is taken to form an 8 character field which replaces the original content of the descriptor tgt. The characters "xyz" are centred within the new field and padded on both sides with the fill character '@'.

Setting the alignment to ELeft would change the content of tgt to "xyz@@@@@" while setting the alignment to ERight would change the content of tgt to "@@@@@xyz"

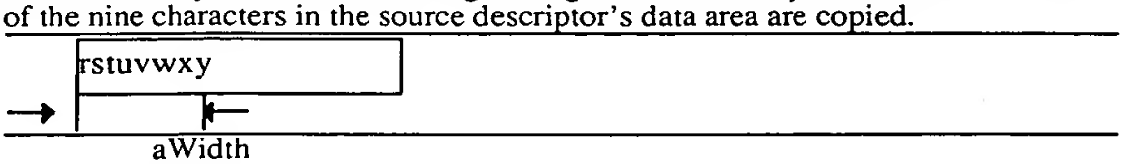
In all three cases, the length of the descriptor tgt changes from 3 to 8.

```
...
TBuf<8> tgt(_L("abc"));
...
tgt.Justify(_L("xyz"),9,ECenter,'@');
```

This call to Justify() will panic because the resulting length of data in tgt would exceed the maximum length of tgt.

```
...
TBuf<16> tgt(_L("abc"));
...
tgt.Justify(_L("rstuvwxyz"),8,ECenter,'@');
```

In this call to Justify(), the content of tgt changes to "rstuvwxy" as illustrated below. Only eight of the nine characters in the source descriptor's data area are copied.



Insertion/deletion

e32.descriptors.TDes.insertion-deletion

Insert() — Insert from descriptor

void Insert(TInt aPos,const TDesC& aDes);

Description

Use this function to insert the content of aDes into *this* descriptor's data area at the specified position. The existing data at the specified position within *this* descriptor is moved to the right to make way for the inserted data.

The length of *this* descriptor is increased to reflect the increase in content.

Arguments

TInt aPos	The offset within *this* descriptor's data area where the content of aDes is to be inserted. This value can range from zero to the length of *this* descriptor. A value of zero means insert at the beginning of *this* descriptor's data area, while a value equal to the length of *this* descriptor means insert at the end (i.e. append). aPos must not be negative and must not be greater than the length of *this* descriptor, otherwise the function will panic with ETDes8PosOutOfRange for the 8 bit variant or ETDes16PosOutOfRange for the 16 bit variant.
const TDesC& aDes	A reference to any type of descriptor whose content is to be inserted into *this* descriptor. The length of aDes plus the length of *this* descriptor must not exceed the maximum length of *this* descriptor otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Example

The following code fragment illustrates the use of Insert().

```
...
TBuf<8> tgt(3);
TPtrC  src(_L("abc"));
...                        // generates the strings...
tgt = src;
tgt.Insert(0,_L("XYZ"));          // "XYZabc"
...
tgt = src;
tgt.Insert(1,_L("XYZ"));          // "aXYZbc"
...
tgt = src;
tgt.Insert(tgt.Length(),_L("XYZ")); // "abcXYZ"
...
tgt = src;
tgt.Insert(tgt.Length()+1,_L("XYZ"));// ----> Panic !!
...
tgt = src;
tgt.Insert(1,_L("WXYZ"));          // "aWXYZbc"
...
tgt = src;
tgt.Insert(1,_L("VWXYZ"));          // "aVWXYZbc"
...
tgt = src;
tgt.Insert(1,_L("UVWXYZ"));         // ----> Panic !!
...
```

Delete() **Delete**

void Delete(TInt aPos,TInt aLength);

Description

Use this function to delete a portion of data of length aLength from *this* descriptor's data area, starting at position aPos.

The length of *this* descriptor is decreased to reflect the reduction in content.

Arguments

TInt aPos	The offset within *this* descriptor's data area where deletion is to start. This value c range from zero to the length of *this* descriptor. A value of zero means delete from the beginning of *this* descriptor's data area, wh a value equal to the length of *this* descriptor means, in effect, that no data will deleted. aPos must not be negative and must not be greater than the length of *this* descript otherwise the function will panic with ETDes8PosOutOfRange for the 8 bit vari: or ETDes16PosOutOfRange for the 16 bit variant.
TInt aLength	The length of data to be deleted from the descriptor. If (aLength + aPos) is greater than the length of *this* descriptor, then the length data deleted is (*this* descriptor length - aPos). In effect, the value of aLength truncated.

Example

The following code fragment illustrates the use of Delete().

```
...
TBuf<8> tgt(4);
TBufC<4> src(_L("abcd"));
...                     // generates the strings
tgt = src;
tgt.Delete(0,1);        // "bcd"
...
tgt = src;
tgt.Delete(0,2);        // "cd"
...
tgt = src;
tgt.Delete(0,4);        // ""
...
tgt = src;
tgt.Delete(1,2);        // "ad"
...
tgt = src;
tgt.Delete(2,2);        // "ab"
...
tgt = src;
tgt.Delete(2,3);        // "ab"
...
tgt = src;
tgt.Delete(2,256);      // "ab"
...
tgt = src;
tgt.Delete(5,1);        // ----> Panics !!
...
tgt = src;
tgt.Delete(-1,1);       // ----> Panics !!
...
```

Replace() — Replace

void Replace(TInt aPos,TInt aLength,const TDesC& aDes);

Description

Use this function to replace a portion of data of length aLength in *this* descriptor's data area, starting at position aPos, with the content of the descriptor aDes.
The length of aDes may be less than aLength, in which case the resulting length of *this* descriptor decreases.
The length of aDes may be greater than aLength, in which case the resulting length of *this* descriptor increases.

The length of *this* descriptor changes to reflect the changed content.

Arguments

TInt aPos	The offset within *this* descriptor's data area where replacement is to start. T value can range from zero to the length of *this* descriptor. A value of zero means replace at the beginning of *this* descriptor's data area aPos must not be negative and must not be greater than the length of *t* descriptor, otherwise the function panics with ETDes8PosOutOfRange for 8 bit variant or ETDes16PosOutOfRange for the 16 bit variant.
TInt aLength	The length of data in *this* descriptor which is to be replaced. aLength must not be negative and (aLength + aPos) must not be greater than current length of *this* descriptor, otherwise the function panics w ETDes8LengthOutOfRange for the 8 bit variant or ETDes16LengthOutOfRan for the 16 bit variant.
const TDesC& aDes	A reference to any type of descriptor whose content is to replace the data length aLength at position aPos in *this* descriptor. The length of aDes must not be negative and must not exceed the maximı length of *this* descriptor otherwise the function panics w ETDes8RemoteLengthOutOfRange for the 8 bit variant ETDes8RemoteLengthOutOfRange for the 16 bit variant. The resulting length of *this* descriptor must not exceed the maximum len *this* descriptor, otherwise the function panics with ETDes8Overflow f 8 bit variant or ETDes16Overflow for the 16 bit variant.

Example

The following code fragment illustrates the use of Replace().

```
...
TBuf<8> tgt(4);
TBufC<4> src(_L("abcd"));
...                     // generates the strings
tgt = src;
tgt.Replace(0,1,_L("u"));     // "ubcd"
...
tgt = src;
tgt.Replace(0,1,_L("uv"));    // "uvbcd"
...
tgt = src;
tgt.Replace(0,1,_L("uvw"));   // "uvwbcd"
...
tgt = src;
tgt.Replace(0,1,_L("uvwxyz"));// ----> Panics !!
...
tgt = src;
tgt.Replace(1,2,_L("u"));     // "aud"
...
tgt = src;
tgt.Replace(1,2,_L(""));      // "ad"
...
tgt = src;
tgt.Replace(1,4,_L("uvw"));   // ----> Panics !!
...
tgt = src;
tgt.Replace(3,1,_L("uvw"));   // "abcuvw"
...
tgt = src;
tgt.Replace(4,0,_L("uvw"));   // "abcduvw"
...
```

Delete leading and trailing spaces

e32.descriptors.TDes.delete-spaces

TrimLeft() — Delete spaces from left side of descriptor

void TrimLeft();

Description

Use this function to delete space characters from the left hand side of the descriptor's data area. The function deletes every space character, starting at the beginning, until it meets the first non-space character.

The length of the descriptor is reduced to reflect the loss of the space characters.

Example

The following code fragment illustrates the use of TrimLeft().

```
...
TBuf<8> str1(_L("  abcd  ")); // generates the following strings
TBuf<8> str2(_L(" a b "));    // in the descriptors str1 and str2
...
str1.Length();          // returns 8
str1.TrimLeft();         // "abcd  "
str1.Length();          // returns 6
...
str2.Length();          // returns 5
str2.TrimLeft();         // "a b "
str2.Length();          // returns 4
...
```

TrimRight() — Delete spaces from right side of descriptor

void TrimRight();

Description

Use this function to delete space characters from the right hand side of the descriptor's data area. The function deletes every space character, starting at the end and moving towards the beginning, until it meets the first non-space character.

The length of the descriptor is reduced to reflect the loss of the space characters.

Example

The following code fragment illustrates the use of TrimRight().

```
...
TBuf<8> str1(_L("  abcd  ")); // generates the following strings
TBuf<8> str2(_L(" a b "));    // in the descriptors str1 and str2
...
str1.Length();          // returns 8
str1.TrimRight();        // "  abcd"
str1.Length();          // returns 6
...
str2.Length();          // returns 5
str2.TrimRight();        // " a b"
str2.Length();          // returns 4
...
```

Trim() — Delete spaces from both sides of descriptor

void Trim();

Use this function to delete space characters from both the left and the right hand sides of the descriptor's data area.

The function deletes every space character starting at the beginning until it meets the first non-space character and deletes every space character starting at the end and moving towards the beginning, until it meets the first non-space character.

The length of the descriptor is reduced to reflect the loss of the space characters.

Example

The following code fragment illustrates the use of Trim().

```
...
TBuf<8> str1(_L("  abcd  "));  // generates the following strings
TBuf<8> str2(_L(" a b "));     // in the descriptors str1 and str2
...
str1.Length();          // returns 8
str1.Trim();            // "abcd"
str1.Length();          // returns 4
...
str2.Length();          // returns 5
str2.Trim();            // "a b"
str2.Length();          // returns 3
...
```

Fold/collate

e32.descriptors.TDes.fold-collate

Fold() — Fold

void Fold();

Description

Use this function to fold the content of *this* descriptor. See e32.descriptors.folding for more information on folding.

Collate() — Collate

void Collate();

Description

Use this function to collate the content of *this* descriptor. See e32.descriptors.collating for more information on collating.

Change case

e32.descriptors.TDes.change-case

LowerCase() — Convert to lower case

void LowerCase();

Description

Use this function to convert the characters in *this* descriptor to lower case.

UpperCase() — Convert to upper case

void UpperCase();

Description

Use this function to convert the characters of *this* descriptor to upper case.

Capitalise() — Capitalise

void Capitalise();

Description

Use this function to capitalise the content of *this* descriptor.

Capitalisation here means the conversion of the first character to upper case and the conversion of all remaining characters to lower case.

Example

The following code fragment illustrates the use of Capitalise()

```
...
TBuf<24> tgt(_L("tHe CaT sAt On ThE mAt."));
...
tgt.Capitalise();  // changes string to
                   // "The cat sat on the mat."
...
```

Filling

e32.descriptors.TDes.filling

Fill() — Fill with character

void Fill(TChar aChar);

Description

Use this function to fill the *this* descriptor's data area with the character aChar, replacing any existing content.

The data area is filled from the beginning up to its *current* length. It is *not* filled to its maximum length.

The length of the descriptor remains unchanged.

Arguments

TChar aChar	The character used to fill the descriptor's data area.

Fill() — Fill with character up to specified length

void Fill(TChar aChar,TInt aLength);

Description

Use this function to fill *this* descriptor's data area with aLength characters aChar, replacing any existing content.

The length of the descriptor is set to aLength.

Arguments

TChar aChar	The character used to fill *this* descriptor's data area.
TInt aLength	The new length of the descriptor. This value must not be negative and must not greater than the maximum length of *this* descriptor otherwise the function v panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for ı 16 bit variant.

FillZ() — Fill with zeroes

void FillZ();

Description

Use this function to fill the *this* descriptor's data area with zeroes (i.e. 0x00 or 0x0000), replacing any existing content.

The descriptor's data area is filled from the beginning up to its *current* length. It is *not* filled up to its maximum length.

The length of the descriptor remains unchanged.

FillZ() — Fill with zeroes up to specified length

void FillZ(TInt aLength);

Description

Use this function to fill the *this* descriptor's data area with aLength zeroes (i.e. 0x00 or 0x0000), replacing any existing content.

The length of the descriptor is set to aLength.

Arguments

TInt aLength	The new length of the descriptor. This value must not be negative and must not greater than the maximum length of *this* descriptor otherwise the function v panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for ı 16 bit variant.

Integer conversion

e32.descriptors.TDes.integer-conversion

Num() — Convert signed integer

void Num(TInt aVal);

Description

Use this function to convert the signed integer aVal into a decimal character representation and place the resulting characters into *this* descriptor's data area, replacing any existing content. If the integer is negative, the character representation is prefixed by a minus sign.

Arguments

TInt aVal — The value to be converted to decimal characters.

Example

The following code fragment illustrates the use of Num().

```
...
TBuf<16> tgt;           // generates the following strings
TInt numpos(176);         // in the descriptor tgt...
TInt numneg(-176);
...
tgt.Num(numpos);          // "176"
tgt.Num(numneg);          // "-176"
...
```

Num(), NumUC() — Convert unsigned integer

e32.descriptors.TDes.integer-conversion.Numusi

void Num(TUint aVal,TRadix aRadix=EDecimal);
void NumUC(TUint aVal,TRadix aRadix=EDecimal);

Description

Use these functions to convert the unsigned integer aVal into its corresponding character representation and place the resulting characters into *this* descriptor's data area, replacing any existing content.

Num() converts the hexadecimal characters 'a', 'b', 'c', 'd', 'e' and 'f' to lower case, while NumUC() converts them to upper case.

The choice of function is dependent on the needs of applications.

Arguments

TUint aVal — The value to be converted to characters.

TRadix aRadix — The number system representation for the unsigned integer. This is an enumeration; see e32.descriptors.TRadix.
If no value is supplied, then EDecimal is taken by default.

Example

The following code fragment illustrates the use of Num() and NumUC().

```
...
TBuf<16> tgt;           // generates the following strings
TUint number(176);        // in the descriptor tgt...
...
tgt.Num(number,EBinary);   // "10101010"
tgt.Num(number,EOctol);    // "252"
tgt.Num(number,EDecimal);  // "176"
tgt.Num(number,EHex);      // "aa"  <-NB hex value in lower case
tgt.NumUC(number,EHex);    // "AA"  <-NB hex value in UPPER case
tgt.Num(number);           // "176"  <--EDecimal taken as default
```

Real number conversion

e32.descriptors.TDes.real-number-conversion

Num() **Convert floating point number**

e32.descriptors.num-float

TInt Num(TReal aVal,const TRealFormat& aFormat);

Description

Use this function to convert the floating point number aVal into a character representation and place the resulting characters into *this* descriptor's data area, replacing any existing content.

The format of the character representation is dictated by aFormat, an object of type TRealFormat. See e32.class.TRealFormat for more information on the TRealFormat class.

Arguments

TReal aVal	The floating point number to be converted. The value must be such that 1.0E-99 <= | aVal | <= 1.0E99. Any value smaller than 1.0E-99 is assumed to be zero.
TRealFormat& aFormat	A reference to a TRealFormat object which dictates the format of the conversion.

Return value

TInt	If the conversion is successful, the length of the converted string. If the conversion fails, a negative value indicating the cause of failure. The possible values and their meaning are as follows:
KErrArgument	The length of the converted number is greater than the maximum length of *this* descriptor. In other words, there is insufficient space in *this* descriptor to hold the character representation.
KErrOverflow	The number is too large to represent
KErrUnderflow	The number is too small to represent
KErrGeneral	The conversion cannot be completed; e.g.the value of the iWidth member of TRealFormat is too small.

Formatting

e32.descriptors.TDes.formatting

Format() **Convert multiple arguments**

e32.descriptors.format

void Format(TRefByValue<const TDesC> aFmt,...);

Description

Use this function to insert formatted text into *this* descriptor, as controlled by the format string supplied in the descriptor aFmt and the argument list which follows it. Any existing content in *this* descriptor is discarded.

The format string contained in aFmt contains literal text, embedded with commands for converting the trailing list of arguments into text.

The embedded commands are character sequences prefixed with the '%' character. The literal text is simply copied into *this* descriptor unaltered while the '%' commands are used to convert successive arguments (which follow aFmt in the argument list).

The resulting stream of literal text and converted arguments is inserted into *this* descriptor.

The syntax of the embedded commands follows one of the four general patterns shown below. Each bracketed item indicates a character or sequence of characters having a specific meaning.

A bracketed item within square brackets is optional.

- %<type>

  where <type> is a character code which indicates how data is to be converted. The data is converted without padding and only occupies the space required.
- %<width>[<prec>]<type>

  where <type> is a character code indicating how data is to be converted and <width> contains either numeric characters which directly define the size of the

field to be occupied by the converted data or an '*' character. An '*' indicates that the size of the field is taken from the next TUint value in the argument list.

<prec> is optional and is only relevant when a real number is to be converted. If specified, <prec> must be a '.' character followed by an integer representing the precision of the real number, (i.e. the number of decimal places). If <prec> is omitted, the precision for the conversion of a real number defaults to KDefaultPrecision.

The converted data is right-aligned within the field; if it occupies fewer character positions than specified in <width>, it is padded to the left with blank characters.

If more than <width> characters are generated by the conversion, then the outcome depends on the value of <type>.

If <type> is either e, E, f, or F, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KMaxRealWidth.

If <type> is either g, or G, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KDefaultRealWidth.

If the source data is any other type, the converted data is truncated so that only <width> characters are taken.

- %0<width>[<prec>]<type>

  where <type> is a character code indicating how data is to be converted and <width> contains numeric characters which directly define the size of the field to be occupied by the converted data.

  The converted data is right-aligned within this field; if it occupies fewer character positions than specified in <width>, it is padded to the left with '0' characters.

  If more than <width> characters are generated by the conversion, then the outcome depends on the value of <type>.

  If <type> is either e, E, f, or F, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KMaxRealWidth.

  If <type> is either g, or G, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KDefaultRealWidth.

  If the source data is any other type, the converted data is truncated so that only <width> characters are taken.

  <prec> is optional and is only relevant when a real number is to be converted. If specified, <prec> must be a '.' character followed by an integer representing the precision of the real number, (i.e. the number of decimal places). If <prec> is omitted, the precision for the conversion of a real number defaults to KDefaultPrecision.

  (*Note:* in this specific case, <width> cannot be a single '*' character. If it is necessary to take the width value from the argument list, use the more general pattern %<a><p><width><type>).

- %<a><p><width>[<prec>]<type>

  where <type> is a character code indicating how data is to be converted and <width> contains either numeric characters which directly define the size of the field to be occupied by the converted data or an '*' character. An '*' indicates that the size of the field is taken from the next TUint value in the argument list.

  <prec> is optional and is only relevant when a real number is to be converted. If specified, <prec> must be a '.' character followed by an integer representing the precision of the real number, (i.e. the number of decimal places). If <prec> is

omitted, the precision for the conversion of a real number defaults to KDefaultPrecision.

The converted data is aligned within this field as defined by the value of <a> as follows:

+ right aligned

- left aligned

= centre aligned

If the converted data occupies fewer character positions than specified in <width>, it is padded with the pad character defined by <p>.

Note that a pad character of '*' is a special case. It indicates that the code value of the pad character is taken from the next TUint value in the argument list. The data for conversion is taken from the *following* argument.

Thus, to pad with asterisks, the code value of the asterisk character must be supplied through the argument list.

If more than <width> characters are generated by the conversion, then the outcome depends on the value of <type>.

If <type> is either e, E, f, or F, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KMaxRealWidth.

If <type> is either g, or G, (the source data is a real number), the value of <width> is ignored and all the generated characters are accepted; however, the maximum number of characters generated can never exceed KDefaultRealWidth.

If the source data is any other type, the converted data is truncated so that only <width> characters are taken.

The conversion of argument data is dictated by the value of <type> which consists of a single character. Note the case of the character as this is significant.

The possible values for <type> are as follows:

b Interpret the argument as a TUint and convert it to its binary character representation. This can be either upper or lower case.

o Interpret the argument as a TUint and convert it to its octal character representation. This can be either upper or lower case.

d Interpret the argument as a TInt and convert it to its *signed* decimal representation. This can be either upper or lower case.
If the value is negative, the representation will be prefixed by a minus sign.

e Interpret the argument as a TReal and convert it to exponent format representation (See e32.class.TRealFormat and e32.enum.TRealFormatType).
(Note the *lower* case)

E Interpret the argument as a TReal96 and convert it to exponent format representation (See e32.class.TRealFormat and e32.enum.TRealFormatType).
(Note the *upper* case)

f Interpret the argument as a TReal and convert it to fixed format representation (See e32.class.TRealFormat and e32.enum.TRealFormatType).
(Note the *lower* case)

F Interpret the argument as a TReal96 and convert it to fixed format representation (See e32.class.TRealFormat and e32.enum.TRealFormatType).
(Note the *upper* case)

g Interpret the argument as a TReal and convert it to either fixed or exponent format representation, whichever format can present the greater number of significant digits (See e32.class.TRealFormat and e32.enum.TRealFormatType).
(Note the *lower* case)

G	Interpret the argument as a TReal96 and convert it to either fixed or exponent format representation, whichever format can present the greater number of significant digits (See e32.class.TRealFormat and e32.enum.TRealFormatType). (Note the *upper* case)
u	Interpret the argument as a TUint and convert it to its *unsigned* decimal representation. This can be either upper or lower case.
x	Interpret the argument as a TUint and convert it to its hexadecimal representation. This can be either upper or lower case.
p	Generate the required number of pad characters. No arguments are accessed. This can be either upper or lower case.
c	Interpret the argument as a TUint value and convert it to a single ASCII character value. This can be either upper or lower case.
s	Interpret the argument as a zero terminated string. Copy the characters from the string but exclude the zero terminator. (Note the *lower* case).
S	Interpret the argument as the *address* of a descriptor and copy the characters from it. (Note the *upper* case).
w	Interpret the argument as a TUint and convert the value to a *two byte* binary numeric representation with the *least* significant byte first. The generated output is two bytes whether *this* descriptor is an 8 bit or a 16 bit variant. (Note the *lower* case).
W	Interpret the argument as a TUint and convert the value to a *four byte* binary numeric representation with the *least* significant byte first. The generated output is four bytes whether this descriptor is an 8 bit or a 16 bit variant. (Note the *upper* case).
m	Interpret the argument as a TUint and convert the value to a *two byte* binary numeric representation with the *most* significant byte first. The generated output is two bytes whether this descriptor is an 8 bit or a 16 bit variant. (Note the *lower* case)..
M	Interpret the argument as a TUint and convert the value to a *four byte* binary numeric representation with the *most* significant byte first. The generated output is four bytes whether this descriptor is an 8 bit or a 16 bit variant. (Note the *upper* case).

Arguments

TRefByValue<const TDesC> aFmt	Any type of descriptor containing the format string. The TRefByValue is constructed from the aFmt.
...	A variable number of arguments to be converted to text as dictated by the format string in aFmt.

Notes

Two successive '%' characters are interpreted as literal text and causes one '%' character to be generated.

Blank characters are interpreted as literal text.

Specifying a pad character of '*' is a special case. It indicates that the code value of the pad character is taken as the *next* TUint value from the argument list. Any data needed for conversion is taken from the *following* argument.

Thus, to use asterisks as a pad character, the code value of the asterisk character must be supplied in the argument list.

Using an '*' character for both <width> and <p> means that the width value and the pad character will be taken from the argument list. Note that the first '*' character will be interpreted as representing the width *only* if it is preceded by one of the alignment characters '+' '-' or '=' (i.e., if the command follows the fourth general pattern outlined above).

Specifying the command %p results in no characters being generated. To be useful, a width needs to specified; for example '%1p' or '%6p'.

If <prec> is specified when the data to be converted is not a real number, then it is ignored.

If any command has incorrect syntax, then the function will panic with ETDes8BadFormatDescriptor for the 8 bit variant or ETDes16BadFormatDescriptor for the 16 bit variant

If the resulting length of text in *this* descriptor exceeds its maximum length, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Example

The following code fragments illustrate the various possibilities of Format().

```
...
TBuf<256> tgt;
...
tgt.Format(_L("[%b %c %d %o %u %x]"),65,65,65,65,65,65);
...                     //generates:
                        //[1000001 A 65 101 65 41]

tgt.Format(_L("[%04x]"),65;
...                     //generates:
                        //[0041]

tgt.Format(_L("[%4x]"),65;
...                     //generates:
                        //[  41]
                        //      note the use of blanks as
                        //      default fill characters

tgt.Format(_L("[%*x]"),4,65;
...                     //generates:
                        //[  41]
                        //      width taken from the
                        //      argument list

tgt.Format(_L("[%+$4d.00 %S]"),65,&(_L("over")));
...                     //generates:
                        //[$$65.00 over]
                        //          note that %ls can be
                        //          replaced by %S

tgt.Format(_L("[%+0*S]"),10,&(_L("fred")));
...                     //generates:
                        //[000000fred]

tgt.Format(_L("[%=*6x]"),'*',65);
...                     //generates:
                        //[**41**]

tgt.Format(_L("[%+**d]"),'.',10,(-65));
...                     //generates:
                        //[.......-65]
```

```
tgt.Format(_L("[%-A4p]"),65);
...                     //generates:
                        //[AAAA]
                        //      and makes no use of the
                        //      argument list

tgt.Format(_L("[%m]"),4660);
...                     //generates:
                        //the character '['
                        //followed by a byte holding 0x12
                        //followed by a byte holding 0x34
                        //followed by the character ']'

tgt.Format(_L("[%M]"),4660);
...                     //generates:
                        //the character '['
                        //followed by a byte holding 0x00
                        //followed by a byte holding 0x00
                        //followed by a byte holding 0x12
                        //followed by a byte holding 0x34
                        //followed by the character ']'

tgt.Format(_L("[%w]"),4660);
...                     //generates:
                        //the character '['
                        //followed by a byte holding 0x34
                        //followed by a byte holding 0x12
                        //followed by the character ']'

tgt.Format(_L("[%W]"),4660);
...                     //generates:
                        //the character '['
                        //followed by a byte holding 0x34
                        //followed by a byte holding 0x12
                        //followed by a byte holding 0x00
                        //followed by a byte holding 0x00
                        //followed by the character ']'

tgt.Format(_L("[%6.2e]"),3.4555);
...                     //generates:
                        //[3.46E+00]

tgt.Format(_L("[%6.2f]"),3.4555);
...                     //generates:
                        //[  3.46]

tgt.Format(_L("[%6.2g]"),3.4555);
...                     //generates:
                        //[3.4555]
```

FormatList() — **Convert multiple arguments**

```
void FormatList(const TDesC& aFmt,VA_LIST aList);
```

Description

This function is equivalent to Format().

Arguments

const TDesC& aFmt	A reference to any type of descriptor containing the format string.
VA_LIST aList	A pointer to a variable number of arguments to be converted to text as dictated by the format string in aFmt.

Appending

e32.descriptors.TDes.appending

Append() — Append a character

void Append(TChar aChar);

Description

Use this function to add a character onto the end of the content of *this* descriptor.
The length of *this* descriptor is incremented by one.

Arguments

TChar aChar	The character to be appended.

Notes

The length of *this* descriptor must be less than its maximum length. If the descriptor is already at its maximum length, any attempt to append another character will cause the function to panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Append() — Append any descriptor

void Append(const TDesC& aDes);

Description

Use this function to append the content of aDes onto the end of the content of *this* descriptor.
The length of *this* descriptor is incremented by the length of aDes.
There is an extra overloaded variation of Append() so that, if *this* descriptor is the 8 bit variant, Append() can take the 16 bit variant of aDes as well as the expected 8 bit variant.
Thus:

- an 8 bit descriptor can be appended onto an 8 bit descriptor
- a 16 bit descriptor can be appended onto a 16 bit descriptor
- a 16 bit descriptor can be appended onto an 8 bit descriptor.

In the case where a 16 bit descriptor is appended to an 8 bit descriptor, each double-byte is appended as a single byte where the value of the double-byte is less than decimal 256. A double-byte value of decimal 256 or greater cannot be appended as a single byte value and, in this case, the single byte is set to a value of decimal 1.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be appended.

Notes

The resulting length of *this* descriptor must not be greater than its maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

Append() — Append from address

void Append(const TUint??* aBuf,TInt aLength);

Description

Use this function to append data of length aLength at address aBuf onto the end of the content of *this* descriptor.
The length of *this* descriptor is incremented by the value of aLength.

Arguments

const TUint??* aBuf	The address of the data to be appended. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLength	The length of the data to be appended.

Notes

The resulting length of *this* descriptor must not be greater than its maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.
The value of aLength must be non-negative otherwise the results may be unpredictable.

AppendFill() — Append with fill characters

void AppendFill(TChar aChar,TInt aLength);

Description

Use this function to add aLength characters aChar onto the end of any existing data in *this* descriptor.

Arguments

TChar aChar	The fill character.
TInt aLength	The number of fill characters to be appended.

Notes

The resulting length of *this* descriptor must not be greater than its maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

---

AppendJustify() — Append any descriptor and justify

e32.descriptors.TDes.appending.appendjustify-anydesc

```
void AppendJustify(const TDesC& aDes,TInt aWidth,
            TAlign anAlignment,TChar aFill);
```

Description

Use this function to copy the content of aDes onto the end of the content of *this* descriptor.
The target area within *this* descriptor is considered to be an area of width aWidth, immediately following the existing data. The source data is copied into this target area and aligned within it as dictated by the value of anAlignment.
If aWidth has the value KDefaultJustifyWidth, then the width of the target area (i.e. the value of aWidth) is re-set to the value of aLength.
If aLength is smaller than the width of the target area, then any spare space within the target area is padded with the fill character aFill.
If aLength is greater than the width of the target area, then the amount of data copied from the location aString is limited to the value of aWidth.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be copied.
TInt aWidth	The width of the target area. This must be one of: • KDefaultJustifyWidth • a non-negative value If it has the value KDefaultJustifyWidth, then it is re-set to the length of aDes. If the value is less than the length of aDes, then the amount of data copied from aDes into the target area is limited to this value.
TAlign anAlignment	An enumeration which dictates the alignment of the data within the target area. See e32.enum.TAlign.
TChar aFill	The fill character used to pad the target area.

Notes

If the width of the target area is greater than the maximum length of *this* descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

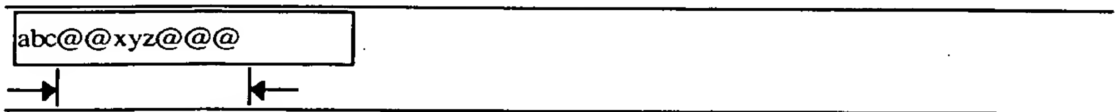
Do not set aWidth to a negative value (other than KDefaultJustifyWidth) as this may have unpredictable consequences.

Example

The following code fragments illustrate the use of AppendJustify().

```
...
TBuf<16> tgt(_L("abc"));
tgt.AppendJustify(_L("xyz"),8,ECenter,'@');
```

The descriptor tgt has a maximum length of 16 and initially holds the string "abc". After the call to AppendJustify(), the content of tgt changes to "abc@@xyz@@@" as illustrated below.



aWidth

In this example, the content of the source descriptor is taken to form an 8 character field which is appended to the content of the descriptor tgt. The characters "xyz" are centred within the new field and padded on both sides with the fill character '@'.

Setting the alignment to ELeft would change the content of tmp to "abcxyz@@@@@" while setting the alignment to ERight would change the content of tmp to "abc@@@@@xyz"

In all three cases, the length of the descriptor tgt changes from 3 to 11.

```
...
TBuf<16> tgt(_L("abcdefghik"));
tgt.AppendJustify(_L("0123456"),7,ECenter,'@');
```

This call to AppendJustify() will panic because the resulting length of tgt would exceed its maximum length.

AppendJustify() — Append part of any descriptor and justify

e32.descriptors.TDes.appending.appendjustify-partdesc

```
void AppendJustify(const TDesC &Des,TInt aLength,TInt aWidth,
        TAlign anAlignment,TChar aFill);
```

Description

Use this function to append data of length aLength from the descriptor aDes onto the end of the content of *this* descriptor.

The target area within *this* descriptor's data area is considered to be an area of width aWidth, immediately following the existing data. The source data is copied into this target area and aligned within it as dictated by the value of anAlignment.

If aWidth has the value KDefaultJustifyWidth, then the width of the target area (i.e. the value of aWidth) is re-set to the value of aLength.

If aLength is smaller than the width of the target area, then any spare space within the target area is padded with the fill character aFill.

If aLength is greater than the width of the target area, then the amount of data copied from aDes is limited to the value of aWidth.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be copied.

TInt aLength	The length of data to be copied from the source descriptor aDes. If this value is greater then the value of aWidth, then it is truncated to the value of aWidth.
TInt aWidth	The width of the target area. This must be one of: (KDefaultJustifyWidth (a non-negative value If it has the value KDefaultJustifyWidth, then it is re-set to the value of aLength. If this value is less than aLength, then the amount of data copied from aDes is limited to aWidth.
TAlign anAlignment	An enumeration which dictates the alignment of the data within the target area. See e32.enum.TAlign.
TChar aFill	The fill character used to pad the target area.

Notes

If the width of the target area is greater than the maximum length of *this* descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Do not set aWidth to a negative value (other than KDefaultJustifyWidth) as this may have unpredictable consequences.

Do not set aLength to a negative value as this may have unpredictable consequences.

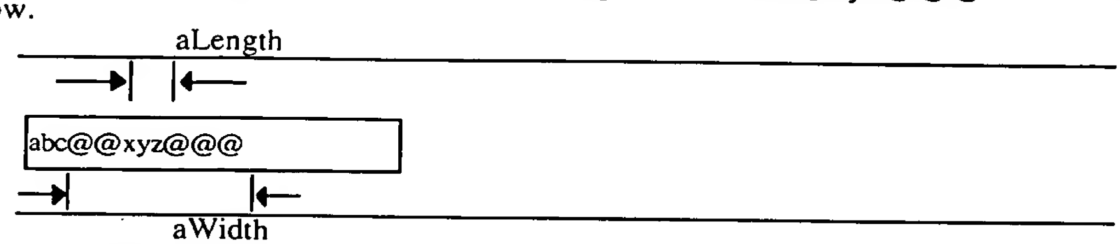
Make sure that the value of aLength is not greater than the length of aDes otherwise unexpected data may be copied.

Example

The following code fragments illustrate the use of AppendJustify().

```
...
TBuf<16> tgt(_L("abc"));
tgt.AppendJustify(_L("xyz01234456789"),3,8,ECenter,'@');
```

The descriptor tgt has a maximum length of 16 and initially holds the string "abc". After the call to AppendJustify(), the content of tgt changes to "abc@@xyz@@@" as illustrated below.



In this example, the first three characters of _L"xyz0123456789" are taken to form an 8 character field which is appended to the existing content of the descriptor tgt. The characters "xyz" are centred within the new field and padded on both sides with the fill character '@'.

Setting the alignment to ELeft would change the content of tgt to "abcxyz@@@@@" while setting the alignment to ERight would change the content of tgt to "abc@@@@@xyz"

In all three cases, the length of the descriptor tgt changes from 3 to 11.

```
...
TBuf<16> tgt(_L("abc"));
tgt.AppendJustify(_L"0123456789",9,8,ECenter,'@');
```

In this example, the call to AppendJustify() changes the content of tgt to "abc01234567". As the specified length is greater than the specified width, the length is truncated so that only eight characters are copied from the source descriptor.

```
...
TBuf<16> tgt(_L("abcdefghik"));
tgt.AppendJustify(_L"0123456789",3,7,ECenter,'@');
```

This call to AppendJustify() panics because the resulting length of tgt would exceed its maximum length.

AppendJustify() — Append from address and justify

e32.descriptors.TDes.appending.appendjustify-fromadr

```
void AppendJustify(const TUint??* aString,TInt aLength,TInt aWidth,
            TAlign anAlignment,TChar aFill);
```

Description

Use this function to append data of length aLength from the address aString onto the end of the content of *this* descriptor.

The target area within *this* descriptor's data area is considered to be an area of width aWidth, immediately following the existing data. The source data is copied into this target area and aligned within it as dictated by the value of anAlignment.

If aWidth has the value KDefaultJustifyWidth, then the width of the target area (i.e. the value of aWidth) is re-set to the value of aLength.

If aLength is smaller than the width of the target area, then any spare space within the target area is padded with the fill character aFill.

If aLength is greater than the width of the target area, then the amount of data copied from the location aString is limited to the value of aWidth.

Arguments

const TUint??* aBuf	The address of the data to be copied and appended. For the 8 bit variant, this is type TUint8*; for the 16 bit variant, this is type TUint16*.
TInt aLength	The length of data to be copied from the location aString. If this value is greater then the value of aWidth, then it is truncated to the value of aWidth.
TInt aWidth	The width of the target area. This must be one of: • KDefaultJustifyWidth • a non-negative value. If it has the value KDefaultJustifyWidth, then it is re-set to the value of aLength. If this value is less than aLength, then the amount of data copied from the location aString is limited to aWidth.
TAlign anAlignment	An enumeration which dictates the alignment of the data within the target area. See e32.enum.TAlign.
TChar aFill	The fill character used to pad the target area.

Notes

If the width of the target area is greater than the maximum length of *this* descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

Do not set aWidth to a negative value (other than KDefaultJustifyWidth) as this may have unpredictable consequences.

Do not set aLength to a negative value as this may have unpredictable consequences.

AppendJustify() — Append zero terminated string and justify

e32.descriptors.TDes.appending.appendjustify-zeroterm

```
void AppendJustify(const TText* aString,TInt aWidth,
            TAlign anAlignment,TChar aFill);
```

Description

Use this function to append the zero terminated string, located at aString, onto the end of the content of *this* descriptor. The zero terminator is not copied.

The target area within *this* descriptor's data area is considered to be an area of width aWidth, immediately following the existing data. The zero terminated string is copied into this target area and aligned within it as dictated by the value of anAlignment.
If aWidth has the value KDefaultJustifyWidth, then the width of the target area (i.e. the value of aWidth) is re-set to the length of the zero terminated string, excluding the zero terminator.
If the length of the zero terminated string (excluding the zero terminator) is smaller than the width of the target area, then any spare space within the target area is padded with the fill character aFill.
If the length of the zero terminated string (excluding the zero terminator) is greater than the width of the target area, then the number of characters copied from aString is limited to the value of aWidth.

Arguments

const TText* aBuf	The address of the zero terminated string to be copied and appended.
TInt aWidth	The width of the target area. This must be one of: (KDefaultJustifyWidth (a non-negative value If it has the value KDefaultJustifyWidth, then it is re-set to the length of the zero terminated string (excluding the zero terminator). If this value is less than the length of the zero terminated string (excluding the zero terminator), then the number of characters copied from aString is limited to aWidth.
TAlign anAlignment	An enumeration which dictates the alignment of the data within the target area. See e32.enum.TAlign.
TChar aFill	The fill character used to pad the target area.

Notes

If the width of the target area is greater than the maximum length of *this* descriptor, then the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.
Do not set aWidth to a negative value (other than KDefaultJustifyWidth) as this may have unpredictable consequences.

AppendNum() **Append converted signed integer**

void AppendNum(TInt aVal);

Description

Use this function to convert the signed integer aVal into a decimal character representation and append the resulting characters onto the end of the content of *this* descriptor. If the integer is negative, the character representation is prefixed by a minus sign.

Arguments

TUint aVal The value to be converted to decimal characters.

Example

The following code fragment illustrates the use of AppendNum().

```
...
TBuf<16> tgt(_L("abc"));    // generates the following strings
TInt numpos(176);           // in the descriptor tgt...
TInt numneg(-176);
...
tgt.AppendNum(numpos);      // "abc176"
tgt.AppendNum(numneg);      // "abc-176"
```

AppendNum(), AppendNumUC() **Append converted unsigned integer**

e32.descriptors.TDes.appending.Appendnumusi

void AppendNum(TUint aVal,TRadix aRadix=EDecimal);
void AppendNumUC(TUint aVal,TRadix aRadix=EDecimal);

Description

Use these functions to convert the unsigned integer aVal into its corresponding character representation and append the resulting characters onto the end of content of *this* descriptor.

AppendNum() converts the hexadecimal characters 'a', 'b', 'c', 'd', 'e' and 'f' to lower case.

AppendNumUC() converts the hexadecimal characters 'A', 'B', 'C', 'D', 'E' and 'F' to upper case.

Arguments

TUint aVal	The value to be converted to characters.
TRadix aRadix	The number system representation for the unsigned integer. This is an enumeration; see e32.descriptors.TRadix. If no value is supplied, then EDecimal is taken by default.

Example

The following code fragment illustrates the use of AppendNum() and AppendNumUC().

```
...
TBuf<16> tgt(_L("abc"));      // generates the following strings
TUint num(176);               // in the descriptor tgt...
...
tgt.AppendNum(num,EBinary);   // "abc10101010"
tgt.AppendNum(num,EOctol);    // "abc252"
tgt.AppendNum(num,EDecimal);  // "abc176"
tgt.AppendNum(num,EHex);      // "abcaa" <-NB hex value in lower case
tgt.AppendNumUC(num,EHex);    // "abcAA" <-NB hex value in UPPER case
                              //    and current descriptor
                              //    content converted to
                              //    upper case.
tgt.AppendNum(num);           // "abc176"<--EDecimal taken as default
```

AppendFormat() — Append converted multiple arguments

e32.descriptors.TDes.appending.AppendFormat

void AppendFormat(TRefByValue<const TDesC> aFmt,...);
void AppendFormat(TRefByValue<const TDesC> aFmt,
TDes??Overflow* aOverflowHandler,
...);

Description

Use this function to append formatted text into *this* descriptor, as controlled by the format string supplied in the descriptor aFmt and the argument list which follows it. The generated text is appended to any existing data within *this* descriptor.

The format string contained in aFmt contains literal text, embedded with commands for converting the trailing list of arguments into text.

See the e32.descriptors.format member function for the syntax of the embedded commands.

The resulting length of this descriptor must not exceed its maximum length. Once the descriptor reaches its maximum length, any attempt to append more text will result in *one* of the following:

- if aOverflowHandler is *not* supplied, the function panics with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.
- if aOverflowHandler *is* supplied, the Overflow() member function of *either* TDes8Overflow for the 8 bit variant *or* TDes16Overflow for the 16 bit variant, is called to handle the condition; On return from Overflow(), AppendFormat() completes without panic.

Arguments

TRefByValue<const TDesC> aFmt	Any type of descriptor containing the format string. The TRefByValue is constructed from the aFmt.
TDes??Overflow* aOverflowHandler	If supplied, a pointer to either a TDes8Overflow object (for the 8 bit variant) or a TDes16Overflow object (for the 16 bit variant). aOverflowHandler->Overflow() is called if an attempt is made to exceed the maximum length of *this* descriptor.
...	A variable number of arguments to be converted to text as dictated by the format string in aFmt.

AppendFormatList() — Append converted multiple arguments

e32.descriptors.TDes.appending.AppendFormatList

```
void AppendFormatList(const TDesC& aFmt,
        VA_LIST aList,
     TDes??Overflow* aOverflowHandler=NULL);
```

Description

This function is equivalent to AppendFormat().

Arguments

const TDesC& aFmt	A reference to any type of descriptor containing the format string.
VA_LIST aList	A pointer to a variable number of arguments to be converted to text as dictated by the format string in aFmt.
TDes??Overflow* aOverflowHandler	If supplied, a pointer to either a TDes8Overflow object (for the 8 bit variant) or a TDes16Overflow object (for the 16 bit variant). aOverflowHandler->Overflow() is called if an attempt is made to exceed the maximum length of *this* descriptor.

AppendNum() — Append converted floating point number

e32.descriptors.appendnum-float

```
TInt AppendNum(TReal aVal,const TRealFormat& aFormat);
```

Description

Use this function to convert the floating point number aVal into a character representation and append the resulting characters onto the end of the content of *this* descriptor.

The format of the character representation is dictated by aFormat, an object of type TRealFormat. See e32.class.TRealFormat for more information on the TRealFormat class.

Arguments

TReal aVal	The floating point number to be converted. The value must be such that 1.0E-99 <= | aVal | <= 1.0E99. Any value smaller than 1.0E-99 is assumed to be zero.
TRealFormat& aFormat	A reference to a TRealFormat object which dictates the format of the conversion.

Return value

TInt	If the conversion is successful, the length of the converted string. If the conversion fails, a negative value indicating the cause of failure. The possible values and their meaning are as follows:

KErrArgument	The length of the converted number is greater than the maximum length of *this* descriptor. In other words, there is insufficient space in *this* descriptor to hold the character representation.
KErrOverflow	The number is too large to represent
KErrUnderflow	The number is too small to represent
KErrGeneral	The conversion cannot be completed; e.g.the value of the iWidth member of TRealFormat is too small.

Add zero terminator

e32.descriptors.TDes.zero-terminator

ZeroTerminate() — Append zero terminator

void ZeroTerminate();

Description

Use this function to append a zero terminator (i.e. a NULL) onto the end of the content of *this* descriptor.

The length of the descriptor is *not changed.*

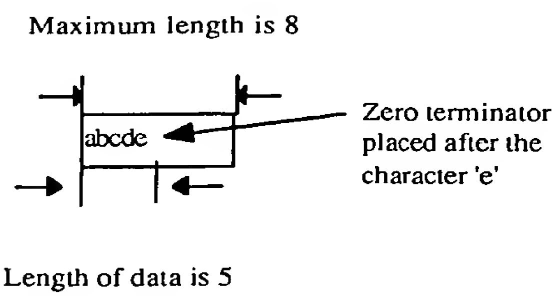
Notes

The length of the descriptor must be strictly less than its maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant. This condition guarantees that there is sufficient space in the descriptor's data area for the zero terminator.

Example

The following code fragment illustrates the use of ZeroTerminate().

```
...
TBuf<8> tgt(_L("abcde"));
...
tgt.ZeroTerminate()
...
```



The length of the descriptor tgt is 5 both before and after the call to ZeroTerminate()

PtrZ() — Append zero terminator and return a pointer

const TText* PtrZ();

Description

Use this function to append a zero terminator (i.e. a NULL) onto the end of the content of *this* descriptor and return a pointer to the descriptor's data area.

The length of the descriptor is *not changed.*

If the data area only contains text characters, then adding a zero terminator creates a 'C' style zero terminated string.

Return value

const TText*	A pointer to the zero terminated string

Notes

The length of the descriptor must be strictly less than its maximum length otherwise the function will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant. This condition guarantees that there is sufficient space in the descriptor's data area for the zero terminator.

The zero terminated string can be accessed through the returned pointer but cannot be changed.

Indexing operators

e32.descriptors.TDes.indexing-operators

operator [] — Operator []

const TUint??& operator[](TInt anIndex) const;
TUint??& operator[](TInt anIndex);

Description

Use these operators to return a reference to a single data item within *this* descriptor (e.g. a text character). The data can be considered as an array of ASCII or UNICODE characters or as an array of bytes (or double-bytes, but not recommended) of binary data.

These operators allow the individual elements of the array to be accessed and changed.

Two variants of the operator are supplied so that it can return a *lvalue* when applied to a non-const argument or an *rvalue* when applied to a const argument. The decision as to which variant to use, is made by the compiler.

Arguments

TInt anIndex	The index value indicating the position of the element within the data area. The index is given relative to zero; i.e. a zero value implies the leftmost data position. This value must be non-negative *and* less than the current length of the descriptor otherwise the operation will panic with ETDes8IndexOutOfRange for the 8 bit variant or ETDes16IndexOutOfRange for the 16 bit variant

Return value

Tuint??&	A non-const reference to the data at position anIndex. The data is of type TUint8& for 8 bit variants and of type TUint16& for 16 bit variants. This is returned when the operator is used to return a lvalue.
const TUint??&	A const reference to the data at position anIndex. The data is of type TUint8& for 8 bit variants and of type TUint16& for 16 bit variants. This is returned when the operator is used to return an rvalue.

Example

The code fragments illustrates the use of operator[].

```
...
TBuf<8> str(_L("abcdefg"));
TChar  ch;
...
str.Length();        // returns 7
ch = str[0];         // ch contains the character 'a'
ch = str[3];         // ch contains the character 'd'
...
str[0] = 'z';        // changes str to "zbcdefg"
str[3] = 'z';        // changes str to "abczefg"
...
ch = str[7];         // Panic !!
str[7] = 'z';        // Panic !!
```

Appending operators

e32.descriptors.TDes.appending-operators

operator += **Operator +=**

TDes& operator+=(const TDesC& aDes);

Description

Use this operator to append the content of aDes onto the end of the content of *this* descriptor. The length of *this* descriptor is incremented by the length of aDes.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be appended.

Return value

TDes&	A reference to *this* descriptor.

Notes

The operator can only be used by classes derived from TDes, specifically TPtr and TBuf.
The resulting length of *this* descriptor must not be greater than its maximum length otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant

Example

The following code fragment illustrates the use of this operator.

```
...
TBuf<16> tgt(_L("abc"));
...
tgt+=(_L("0123456789"));        // generates "abc0123456789"
tgt+=(_L("0123456789qwerty"));  // Panics !!
```

Non-class specific assignment operators

e32.descriptors.TDes.assignment-operators

The behaviour of these operators is exactly the same as the class specific operators. However, unlike the class specific operators, these non-class specific operators are *not* inline.
The compiler invokes these non-class specific assignment operators whenever the left hand variable of an assignment operation is *not* of a concrete type i.e. one of TPtr, TBufC<class S>, TBuf<class S> or HBufC.
For example,

```
class TMyClass
      {
public :
      void MyCopy(TDes& aTarget, TDesC& aSource);
      }

void TMyClass::MyCopy(TDes& aTarget, TDesC& aSource)
      {
      aTarget = aSource;  // Non-class specific operator used.
      }
{
TBuf<16> target;
TBufC<16> source(_L("ABCDEF"));

TMyClass mine;

mine.MyCopy(target,source);
```

If the member function MyCopy is changed so that it is prototyped as:

```
void MyCopy(TBuf<16>& aTarget, TDesC& aSource);
```

or even

void MyCopy(TBuf<16>& aTarget, TBufC<16>& aSource);

then the TBuf<class S> class assignment operator would be used by the compiler. However, such a change could compromise the design of the class TMyclass.

---

operator = **Operator = taking any descriptor**

TDes& operator=(const TDesC& aDes);

Description

This assignment operator copies the content of any type of descriptor aDes into *this* descriptor.

The content of aDes is copied into *this* descriptor, replacing the existing content. The length of *this* descriptor is set to the length of aDes.

Arguments

const TDesC& aDes	A reference to any type of descriptor whose content is to be copied.

Return value

TDes&	A reference to *this* descriptor.

Notes

This assignment operator returns a reference to type TDes, i.e. the base abstract class for modifiable descriptors.

The length of aDes must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

---

operator = **Operator = taking a modifiable descriptor**

TDes& operator=(const TDes& aDes);

Description

This assignment operator copies the content of a modifiable descriptor aDes into *this* descriptor.

The content of aDes is copied into *this* descriptor, replacing the existing content. The length of *this* descriptor is set to the length of *aDes*.

Arguments

const TDes& aDes	A reference to a modifiable type descriptor whose content is to be copied.

Return value

TDes&	A reference to *this* descriptor.

Notes

This assignment operator returns a reference to type TDes, i.e. the base abstract class for modifiable descriptors.

The length of aDes must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

---

operator = **Operator = taking zero terminated string**

TDes& operator=(const TText* aString);

Description

This assignment operator copies a zero terminated string, excluding the zero terminator, into *this* descriptor.

The copied string replaces the existing content of this descriptor.

The length of *this* descriptor is set to the length of the string (excluding the zero terminator).

Arguments

const TText* aString	The address of the zero terminated string to be copied.

Return value

TDes&	A reference to *this* descriptor.

Notes

This assignment operator returns a reference to type TDes, i.e. the base abstract class for modifiable descriptors.

The length of aDes must not be greater than the maximum length of *this* descriptor otherwise the operation will panic with ETDes8Overflow for the 8 bit variant or ETDes16Overflow for the 16 bit variant.

TDes8Overflow class — Overflow handler (8 bit)

Overview

Derivation

TDes8Overflow — Abstract: 8 bit variant overflow handler.

Defined in

e32des8.h

Description

A TDes8Overflow derived object is used by the AppendFormat() and AppendFormatList() member functions of 8 bit variant descriptors to handle descriptor overflow.

Overflow occurs if an attempt is made to append text to the descriptor when the descriptor is already at its maximum length.

The class is abstract and defines the pure virtual member function Overflow().

See e32.descriptors.TDes.appending.AppendFormat and e32.descriptors.TDes.appending.AppendFormatList.

Writing derived classes

A derived class must provide an implementation for the Overflow() member function.

Overflow handling

Overflow() — **Overflow handler function**

virtual void Overflow(TDes8& aDes);

Description

A pure virtual function.

The function is called by the AppendFormat() and the AppendFormatList() member functions of an 8 bit variant descriptor if an attempt is made to append text to this descriptor when the descriptor is already at its maximum length.

A derived class must provide an implementation for this function.

Arguments

TDes8& aDes	A reference to the 8 bit variant modifiable descriptor whose overflow has resulted in the call to this function

TDes16Overflow class — Overflow handler (16 bit)

Overview

Derivation

TDes16Overflow — Abstract: 16 bit variant overflow handler.

Defined in

e32des16.h

Description

A TDes16Overflow derived object is used by the AppendFormat() and AppendFormatList() member functions of 16 bit variant descriptors to handle descriptor overflow.

Overflow occurs if an attempt is made to append text to the descriptor when the descriptor is already at its maximum length.

The class is abstract and defines the pure virtual member function Overflow().

See e32.descriptors.TDes.appending.AppendFormat and e32.descriptors.TDes.appending.AppendFormatList.

Writing derived classes

A derived class must provide an implementation for the Overflow() member function.

Overflow handling

Overflow() — **Overflow handler function**

virtual void Overflow(TDes16& aDes);

Description

A pure virtual function.

The function is called by the AppendFormat() and the AppendFormatList() member functions of an 16 bit variant descriptor if an attempt is made to append text to this descriptor when the descriptor is already at its maximum length.

A derived class must provide an implementation for this function.

Arguments

TDes16& aDes	A reference to the 16 bit variant modifiable descriptor whose overflow has resulted in the call to this function

TRadix enum — Number system representation

e32.descriptors.TRadix

Defined in

e32std.h

Description

An enumeration whose enumerators govern the number system representation of signed and unsigned integers when converting them into character format.

The enumeration is used by the descriptor member functions e32.descriptors.TDes.integer-conversion.Numusi and e32.descriptors.TDes.appending.Appendnumusi.

Members

EBinary	Conversion into binary character representation.
EOctal	Conversion into octal character representation.
EDecimal	Conversion into decimal character representation.
EHex	Conversion into hexadecimal character representation

TAlign enum — Alignment of data

Defined in

e32std.h

Description

An enumeration whose enumerators govern the alignment of data within an area. The enumeration is used by the descriptor member functions e32.descriptors.TDes.copy-justify.justify, e32.descriptors.TDes.appending.appendjustify-anydesc, e32.descriptors.TDes.appending.appendjustify-partdesc, e32.descriptors.TDes.appending.appendjustify-fromadr and e32.descriptors.TDes.appending.appendjustify-zeroterm.

Members

ELeft	Data is left aligned.
ERight	Data is right aligned.
ECenter	Data is centered.

_S macro — Build independent string

Defined in

e32def.h

Description

```
#if defined(_UNICODE)
typedef TText16 TText;
...
#define _S(a) ((const TText *)L ## a)
#else
typedef TText8 TText;
...
#define _S(a) ((const TText *)a)
#endif
```

Notes

The definition of _S in e32std.def is intertwined with the definition of _L.

_L macro — Build independent literal

Defined in

e32def.h

Description

```
#if defined(_UNICODE)
typedef TText16 TText;
#define _L(a) (TPtrC((const TText *)L ## a))
...
#else
typedef TText8 TText;
#define _L(a) (TPtrC((const TText *)(a)))
...
#endif
```

Notes

The definition of _L in e32std.def is intertwined with the definition of _S.

_S8 macro — 8 bit string

Defined in

e32def.h

Description

```
#define _S8(a) ((const TText8 *)a)
```

_L8 macro — 8 bit literal

Defined in

e32def.h

Description

```
#define _L8(a) (TPtrC8((const TText8 *)(a)))
```

_S16 macro — 16 bit string

Defined in

e32def.h

Description

```
#define _S16(a) ((const TText16 *)L ## a)
```

_L16 macro

16 bit literal

Defined in

e32def.h

Description

```
#define _L16(a) (TPtrC16((const TText16 *)L ## a))
```

Glossary definitions

Term	Aliases	Meaning	See Also
built-in type	n	Data types which are part of the C++ language; e.g. unsigned int, unsigned char etc	
descriptor	n	An object capable of representing contiguous data and providing member functions to operate on that data.	
huffman encode	v	A process of compressing data.	
huffman decode	v	A process of de-compressing data which was originally compressed using Huffman encoding.	
length	n	The length of data currently represented by a descriptor.	
maximum length	n	The maximum length of data which a modifiable type descriptor is capable of holding.	
fold	v	The removal of differences between characters that are deemed unimportant for the purposes of inexact or case-insensitive matching. As well as ignoring differences of case, folding ignores any accent on a character.	
collate	v	The removal of differences between characters that are deemed unimportant for the purposes of ordering characters into their collating sequence	
unicode		ISO 10646-1 defines a "universal character code" which uses either 2 or 4 bytes to represent characters from a large character set. Thus, Far Eastern character sets can be represented. In ERA, 2-byte UNICODE support is built deep into the system.	

Appendix 2

EPOC32 White Paper/Overview

EPOC32 Overview

Author	Martin Tasker, Software Development Kits Manager, Psion Software plc
Revision	3
Date	10th June 1997

This paper is intended to give sufficient information to form a sound technical evaluation of the EPOC32 operating system. It has five main sections, showing in turn the goals of EPOC32, how the components fit together, the EIKON GUI, some very powerful components that are widely re-used throughout the system, and the software development options.

1. Goals of EPOC32

1.1 Mobile ROM-based devices

EPOC32 is an entirely new operating system designed for mobile ROM-based devices, ranging in a spectrum from handheld computers, whose primary focus is standalone power but which add built-in comms, to mobile telephones, whose primary focus is voice communication but which also feature data capabilities.

Today's handheld computers are much more powerful than those of previous generations. An operating system must therefore deliver considerable sophistication in order to effectively utilize the hardware.

Even so, handheld machines are not as powerful as desktop machines. Desktop machines have also improved considerably, so that compared with the same generation of desktops, a handheld will always have less memory, a slower processor, and a smaller screen.

Neither is a handheld like a notebook PC. Today's notebook PCs are red hot — in every sense of the word. Miniaturization has enabled manufacturers to pack high-quality LCDs, fast Pentium-class processors, hard disks and CD-ROM drives into a portable package — but the package is portable only in a brief case, and it uses so much power that, using leading-edge rechargeable battery technology, it can function for at most a few hours.

Handheld machines derive their power not from extravagantly powerful electronics, but from portability and personal convenience. This means a machine whose total weight is less than a notebook's battery pack, which can run for 30 hours on 2 alkaline AA batteries, available at reasonable price anywhere in the world. It also means ergonomics designed around a smaller, lower-contrast, screen, and a pen rather than a mouse. In order to meet these requirements, EPOC32 was designed specifically for its target environment.

1.2 Personal convenience

Mobility is the starting point for personal convenience. If the device is with you everywhere, and instantly available, then its applications must also be instantly available. EPOC32 achieves this by multi-tasking, allowing any number of applications to run at once. It is a one-touch operation to switch between any application and any other.

EIKON, EPOC32's graphical user interface, has been optimized for personal convenience. EPOC32 uses real-world metaphors where appropriate for its applications — cards for the Data program, a notebook for the Agenda. But on the other hand, comfortable PC-type metaphors, such as menus, dialogs and toolbars, are used for most interaction with the machine. Most users will already have some level of PC familiarity. For such users, learning the few idioms required to use EPOC32 effectively will take little time. EPOC32 uses stylish graphical design, carefully chosen menu, dialog and error text, and other types of attention to detail, which maximize its appeal for all types of user.

1.3 Industrial strength

Personal convenience demands industrial strength. If a handheld computer is to be carried like an old paper diary or organizer, then the data on that machine must be accessible at least as quickly as it was on the old paper-based system. This implies continually available applications — no system reboots, no long waits and hour-glasses while applications launch. In turn, this implies good industrial-strength multi-tasking. Even more than continually available applications, the system and applications must be sufficiently robust to prevent loss of user data, whether due to hardware or software. On a personal device, data is very precious.

Multi-tasking operating systems exist in desktop and larger systems, but for handheld devices the environment is more hostile. ROM-based software must be delivered to high standards of quality, because it is hard to fix. Memory is limited: it cannot be squandered. Since there is no hard disk, virtual memory is not available. Resources must be freed when they are finished with: leakage would cause a system failure eventually. It is especially important that partially allocated resources should be freed when an operation fails because of insufficient resources. Power management is vital because, if power is lost from both main and backup battery, all the user's data is lost.

EPOC32 is based on a microkernel which schedules threads pre-emptively, and uses a memory management unit (MMU) to provide separate address spaces for each process. Processes are therefore isolated from each other. A few vital system-wide services (such as thread creation, semaphores and timers) are provided by the kernel. Other system services are provided by a variety of other servers, such as the file server, window server, serial communications server and others. The kernel, and all servers, keep track of their clients' resource usage and, when a client thread terminates, all associated resources are cleaned up.

Whether it is an application or a server, a thread may run for months. Within each thread, errors are reported by a Leave() function and may be trapped by either system or application code. As part of leave processing, automatic cleanup deals with partially-allocated resources, and prevents memory and other resource leakage.

1.4 Real-time

Increasingly, personal devices are used for communications. Traditional communications devices have had real-time operating systems. There is a class of personal communicator devices which use two processors — one using a conventional operating system for data, another using a real-time system for comms. It is highly desirable to be able to use a single system for both purposes.

The critical measure of a real-time system is maximum thread latency — the time between an interrupt occurring, and a thread being able to handle it. In the context of GSM, for instance, certain responses must occur within milliseconds of an event, to a tolerance of only

a few hundred microseconds. The maximum thread latency, no matter what processing is being performed at the time, must therefore be less than this tolerance.

EPOC32 achieves real-time performance in two ways. Firstly, its server-based architecture allows it to run with interrupts always enabled, except for a few short instruction sequences. This means that interrupt latency — the time between an interrupt occurring, and an interrupt service routine being scheduled — is typically a few tens of microseconds (for an ARM 7100 at 18MHz). Typical thread latency is only a little longer than this: if no higher-priority thread is running, the thread latency is limited by the time it takes the interrupt service routine to decide what to do, to post the thread's request semaphore, and have the executive schedule the thread.

Secondly, EPOC32 provides *superthreads*, which run as kernel extensions, and run at a higher priority than the kernel server. Superthreads' maximum latency is 100 microseconds on an 18MHz ARM 7100. By contrast, user threads, running at a lower priority than the kernel server, have a maximum latency limited by the longest-running kernel service, which at 35 milliseconds is still very respectable.

1.5 Scalability

EPOC32 has been optimized for handheld mobile devices. Such devices require considerable software power. EPOC32's robust design has been inspired by industrial-strength workstation environments such as Unix, or Windows NT. Its industrial-strength multi-processing architecture allows it to scale upwards to meet very high demands for personal computing power.

EPOC32 also supports lower-end scalability by several means. Firstly, its resources are all owned by threads, rather than processes. This allows EPOC32 to be configured as a single-process system with relative ease. A single-process system has no inter-thread protection but, on the other hand, it has no MMU in hardware, and therefore no memory management code in ROM, no page tables in RAM, and much lower cost in time of switching between one thread and another. Such a system is ideal for embedded devices with no facility for user-installed software.

As it happens, such a single-process a system is also much easier to implement under Win32 than a full multi-process system. The WINS development environment is therefore a single-process variant of EPOC32.

EPOC32's component-based architecture allows a selection of relevant components to be chosen for a particular application. For instance, a low-end device could omit some communications protocols, some of the engine support and graphics component, and could replace the EIKON GUI altogether, with a smaller GUI, tailored for a machine whose form factor differs significantly from EIKON's design point.

This scalability gives EPOC32 enormous power and flexibility. Although Psion Software's strategy is presently to target EPOC32 at the central area of personal mobile applications, EPOC32 could also find real use in embedded systems, set-top boxes and a variety of other applications in which small size, responsiveness and programming power are important requirements.

1.6 Powerful software development

Without powerful software tools, it would be infeasible to develop either a system of EPOC32's size, or applications for that system. Psion Software chose to use the C++ language, and the leading Microsoft Visual C++ development environment, for the overwhelming majority of software development. Programs are initially developed under

Microsoft Visual C++, on a PC running Microsoft Windows NT (or Windows 95). When ready, programs are then cross-compiled using the highly effective GNU C++ compiler for the target MARM processor.

Software development relies on ideas as well as tools. The most powerful idea in EPOC32 is object orientation and its theoretical corollary, re-use. Object orientation is an extremely powerful design tool: viewed at all levels, EPOC32 is a system of objects.

C++ is a natural, mainstream, object-oriented language, which allows object-oriented designs to be implemented easily. Although C++ has a reputation in some quarters for being slow and bloated, this is by no means necessarily the case. EPOC32 demonstrates that, by achieving re-use of source code and object code *in practice* at all levels, C++ may be used to write highly efficient, compact systems.

1.7 Multi-platform

EPOC32 has been designed to support a variety of hardware platforms. Software was originally developed under Windows NT — the WINS platform, so-called because it uses the **Win**32 API, and only a single process.

The first port to a target machine platform (designated by a leading M) was to MX86. This platform was used to develop the device driver and MMU technology, taking advantage of the existing body of EPOC32 user code compiled for WINS under Microsoft Visual C++, and using the world's best hardware debugging tools which have been developed to support the PC market. Under the MX86 platform, EPOC32 boots natively on a PC without support from any other operating system. This platform is not intended for anything other than a development tool.

The intended target platform is MARM — the ARM architecture from ARM Ltd. The ARM's true RISC architecture is the most efficient in the industry, offering the best MIPS/watt available. Additionally, ARM Ltd's licensing strategy, allowing any of a number of silicon foundries to manufacture licensed designs, gives ARM products a very competitive MIPS/$ figure. Combined, these factors make the ARM architecture by far the most favourable platform for mobile computing devices. Initially, EPOC32 has been targetted at an 18.432MHz ARM 7100, designed by Psion Software and manufactured by Cirrus Logic Inc as the CL-PS7110. Psion Software is porting EPOC32 to Digital Equipment Corp's StrongARM architecture, running at speeds between 100 and 200MHz and maintaining the same tradition of cost- and power-efficiency.

EPOC32 has already been proven as a multi-platform operating system. However, since binary compatibility is important to both Psion Software and application developers, Psion Software does not plan to support any other target machine platforms apart from ARM and StrongARM. Developers will be able to deliver applications as a single set of binaries, and will not have to test their builds against multiple architecture variants.

1.8 Desktop PC connectivity

EPOC32 is not a PC companion operating system. Its applications are of sufficient power that an EPOC32-based machine serves as a fully functioning mobile computer.

However, many — if not most — users also have PCs, and EPOC32 has been designed to gain the most from the desktop machine. Psion Software's EPOC Connect software runs on a Microsoft Windows-based PC to provide integration facilities (EPOC Connect is badged variously by licensees: Psion Computers' PsiWin 2.0 product is an example).

Using EPOC Connect, the PC and EPOC32 machine can see each other's disks, and access and transfer data. Backup and restore for the EPOC32 machine is supported, with a range of partial restore options. File format conversion, and agenda synchronization at record and even field level, are supported. The EPOC32 machine may use the Windows printing system to print: this avoids the inconvenience of changing printer cables, and allows EPOC32 to drive any Windows-supported printer in addition to those it supports natively.

EPOC Connect supports a range of file formats — from Microsoft, Lotus and Corel — and a range of applications — word processors, spreadsheets, databases and PIMs. Round-trip format conversions preserve many features. The architecture of EPOC Connect is extensible, so that converters for new releases, or different vendors' products, may be written.

Psion Software also encourages third-party development of connectivity to non-PC platforms, including a forthcoming Apple Macintosh connectivity product.

1.9 International

EPOC32 is an international operating system. It supports localization in a variety of Western languages using the Windows Latin 1 and Windows Latin 2 character sets. These are the "narrow" builds of EPOC32, which allow text data to be represented compactly in Western markets.

EPOC32 has also been designed for "wide" builds, using the UNICODE character set for all internal purposes, and additionally a variety of other character sets (such as shift-JIS) for data interchange. Psion Software, together with Psion's Far Eastern subsidiaries, is working on the input method editors and enhancements to text formatting and GUIs, required to support Far Eastern locales.

1.10 Psion's track record

The Psion Group of companies has long experience in developing hardware and software for personal, mobile, devices. Beginning with the Psion Organiser in 1984, and the Organiser II in 1986, Psion popularized the concept of mobile computing in both the consumer and the industrial sector. The Organiser II range has sold over a million units, and is still selling.

A major breakthrough came in 1991 with the introduction of the Series 3 range, based on EPOC16. This range has had world-beating success: Psion passed the million-unit mark in early 1997. Although documents are limited to 64k in length, and there is no pen-based interface, the power of the applications and usability of the machines have made the Series 3c and Siena ranges fair competition even for rival 32-bit products.

For EPOC16, Psion invented its own object system based on the C language and a preprocessor. This gave Psion's architects an appreciation of the power of object orientation, and many powerful ideas which have been developed and re-used in EPOC16.

Psion also builds on strong international experience: EPOC16 has been localized into almost every European language, with 15 locales supported, including Hungarian and Czech, Russian and Greek.

EPOC32 improves on EPOC16 in several key areas. Firstly, it uses entirely 32-bit technology, removing 64k limits and their associated difficulties in memory management, DLL size, and document size. Secondly, it is written in C++, a mainstream language, which gives access to existing programming skills, and world-class development tools. Psion's previous experience with handheld machines and object-oriented technology combine to lend EPOC32 a rare degree of maturity and practicality in object-oriented systems. The use

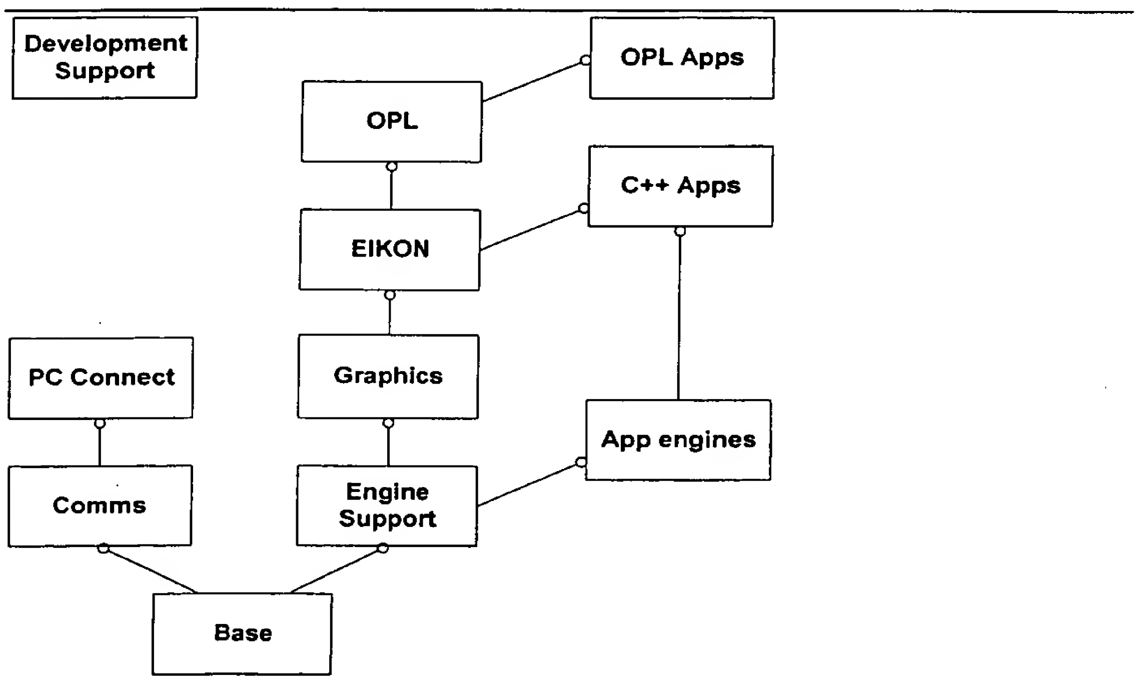
of C++ for all EPOC32 applications, and the vast majority of the system, contributes to its portability.

EPOC32's GUI adds support for a pen device in addition to the keyboard. This supports more intuitive user interfaces, and allows natural user input for drawing programs which, in turn, take full advantage of the large data sizes supported by the 32-bit architecture.

EPOC32 adds to EPOC16's locale support in that it was designed from the start with wide character sets in mind, to allow Far Eastern localization.

Finally Psion has designed EPOC32 from the beginning with licensing in mind. EPOC32's component-based architecture increases the technical feasibility of various kinds of licensing deal. Psion Software was formed as a separate company in 1996, in order to focus exclusively on developing and licensing the platform to new licensees. This will ensure that EPOC32 is available on a wide variety of hardware platforms, and becomes an attractive choice for users and developers alike.

2. Shape of EPOC32



EPOC32 components

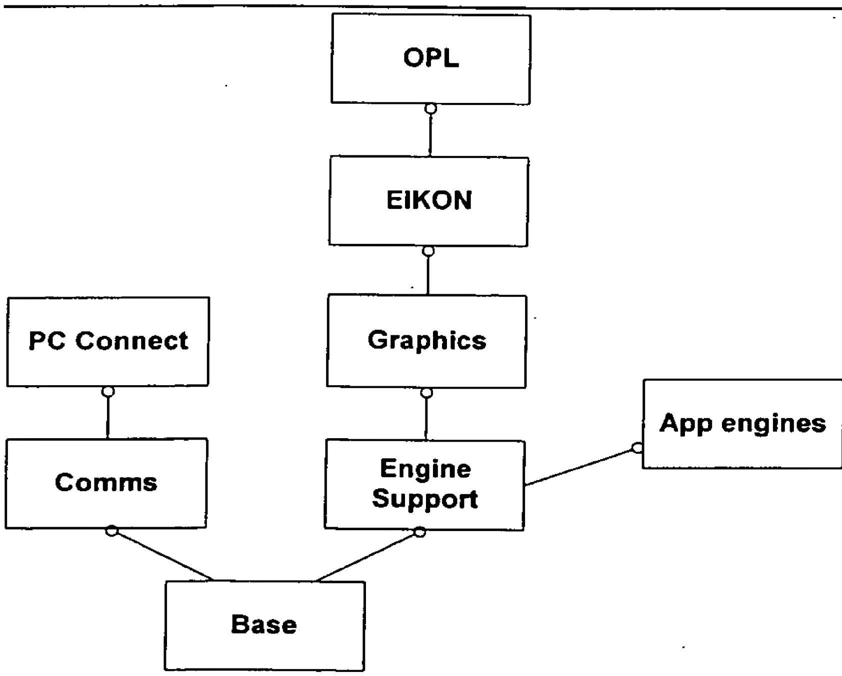
EPOC32 consists of a central tower of software components, from the Base to EIKON. These form the main components used by all C++ applications. OPL, a BASIC-like rapid-application development language, also provides access to all EPOC32 system components. Integral communications and PC connectivity complete the picture of the system. A variety of tools supports development of applications, conversion of picture and sound formats, etc.

Booch notation

Psion Software uses Booch notation to describe EPOC32. Throughout this paper, only one Booch construct will be used, as shown above. The boxes represent components, and the line with an open circle means "uses". So, the picture above means "EIKON uses CONE". Although Booch notation can be quite precise and formal, usually some precision is omitted to gain greater clarity. For instance, graphics uses comms (for printing), but we omit that dependency from the diagram because it is a back-door implementation thing, rather than something essential to the whole purpose of graphics.

2.1 Platform components

2.1.1 Machine platforms and WINS emulator

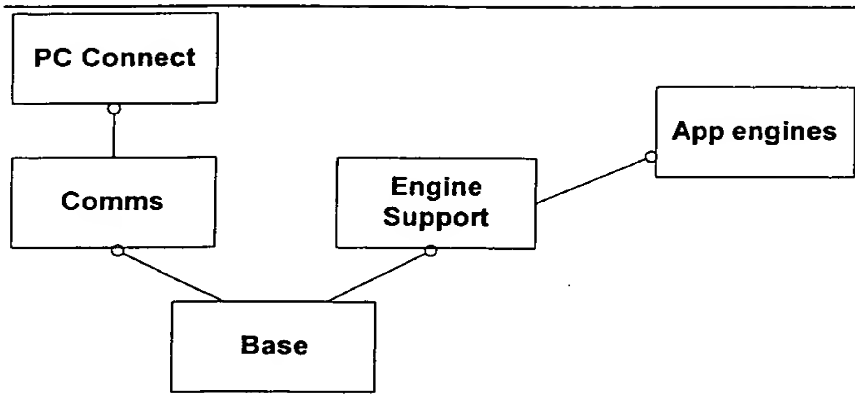


Common platform components

The target machine platforms of EPOC32, and the WINS emulator, support the exactly the same components. Applications may be built to use all the components shown above.

The WINS platform runs under Windows NT or Windows 95. Applications are developed first under Microsoft Visual C++ for the WINS platform, and are debugged with the aid of Microsoft's powerful debugger. Then, the same source code is cross-compiled for the target MARM platform, and uploaded to a target machine for execution.

2.1.2 WINC Platform



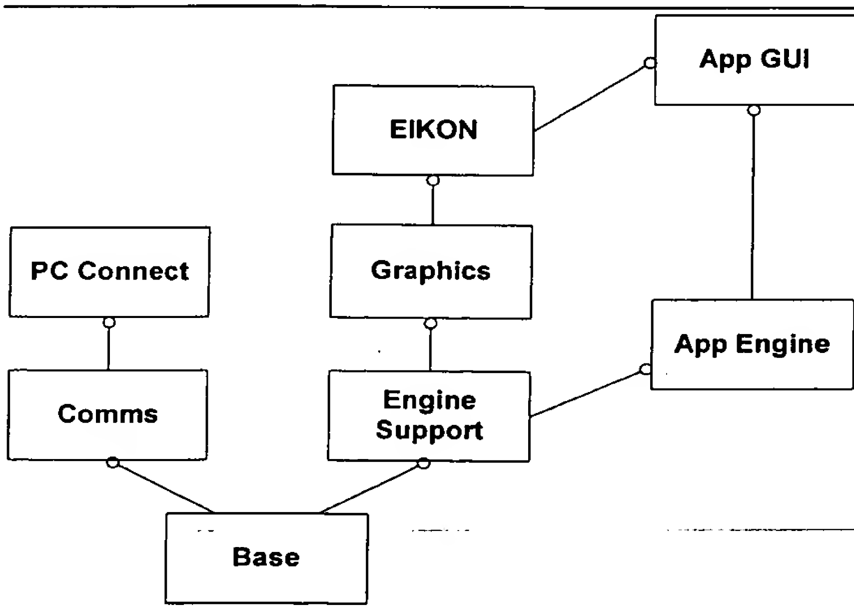
WINC platform

The WINC platform runs on the PC, using the **Win32** API, for connectivity and file format conversion. The WINC platform has no graphics, and the file server may access any file available to the PC.

2.1.3 Application engines

The WINC platform relies on another EPOC32 concept: that of application *engines*. In C++, it's sometimes appropriate to think of the member functions of a class as the only way to access its member variables. On a much larger scale, the API of the application engine is the only way to access an application's data — including its file format. Therefore, instead of publishing file formats for such purposes as format conversion on the PC, EPOC32 applications simply make available their application engines.

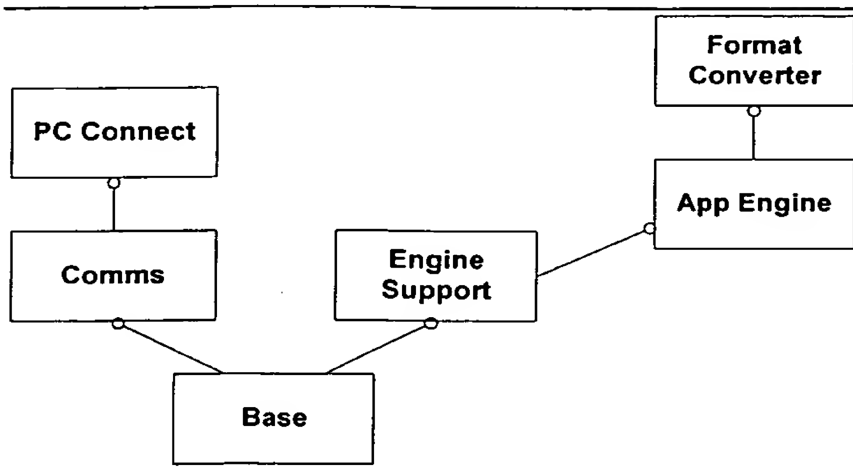
2.1.4 Engines and application GUIs



App engine being driven by app GUI on a machine

In normal use on a machine, the engine is driven by the application's GUI. The GUI and engine are therefore separate components.

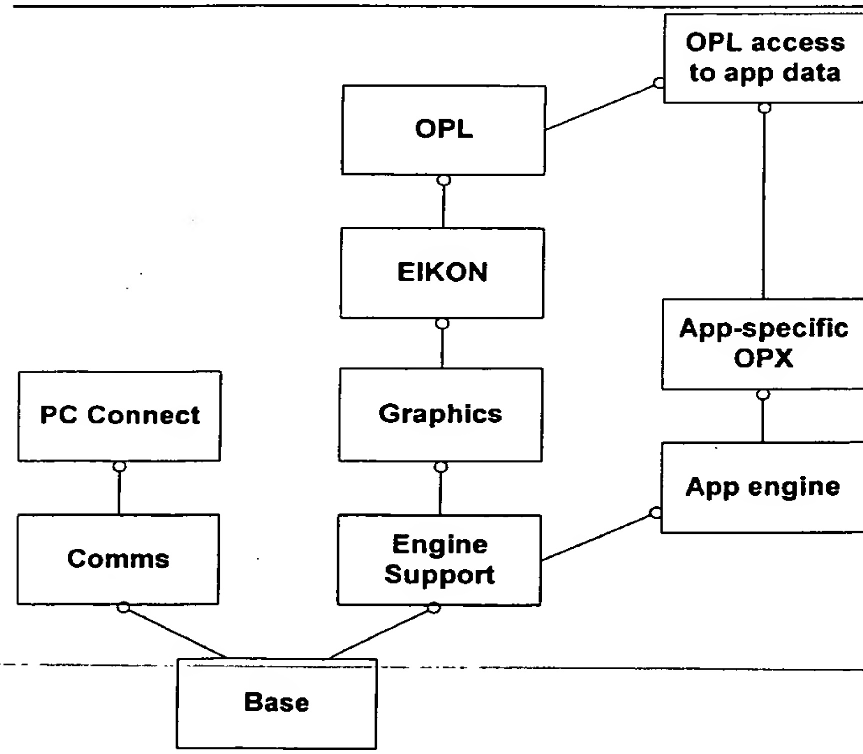
2.1.5 Engines and format conversion



App engine being driven by converter under WINC

For converting file formats, the engine is run under the WINC platform. For converting formats, only the data is needed: graphics components and the GUI itself are unnecessary. The engine is driven by a converter which, on a PC, will usually be a Windows program. The same basic setup is used for conversion both to and from EPOC32 formats, and also for synchronization at field and record level.

2.1.6 App engines and OPL



App engine being driven by OPX for RAD on target machine

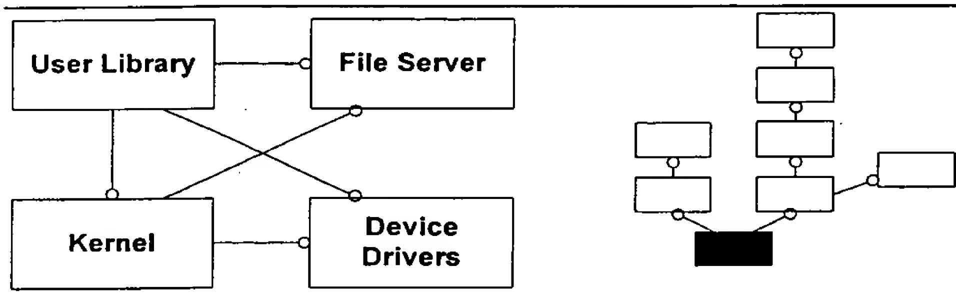
An app engine may also be used to promote rapid application development on a machine. In EPOC16, many programs were written to access files produced by the built-in applications and so provide an interface between PIM data and some other application. Under EPOC32,

this can be achieved in the OPL language by writing an OPX to provide some of the app engine's API to an OPL program. Users of this technique must be aware that EPOC32 applications do not support concurrent access to a single data file.

2.1.7 Benefits of engines

Apart from WINC conversion, and OPX wrappers, engines have good software engineering benefits, and Psion Software encourages application authors to divide any non-trivial application into an engine and a graphical user interface (GUI). The engine development can concentrate on function and robustness, and can be stress-tested by carefully designed test code which would be hard to run through a GUI. In turn, GUI development can concentrate on aesthetics and usability.

2.2 Base



Base component

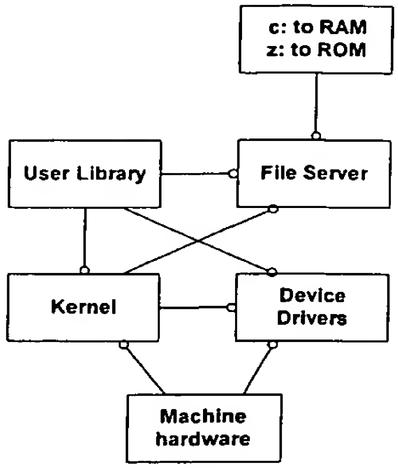
The base provides the programming framework for all other components in EPOC32. Once, the base itself would have been thought of as an entire operating system.

The main user-visible parts of the base are the user library and the file server. Regardless of the platform on which the base is implemented, the user library and file server present a consistent API to user programs.

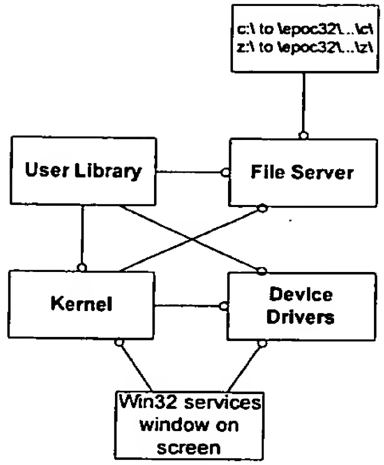
The kernel manages the machine resources, and device drivers drive each hardware device. Device drivers are mostly kernel-side: in addition, each device driver provides a user-side library which allows user threads to access the device's facilities. The kernel and device drivers implement the required EPOC32 functions in different ways depending on the underlying platform.

2.2.1 Base on various platforms

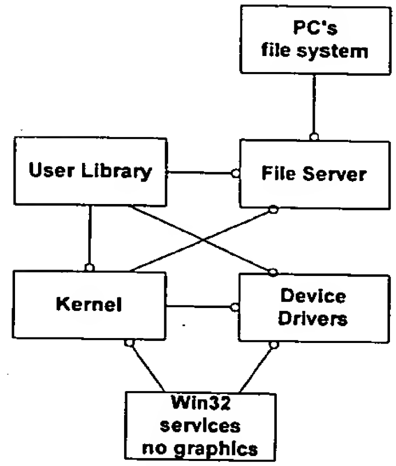
The base is responsible for providing the same API to user programs, regardless of the particular EPOC32 platform. On each platform, the base interfaces with underlying hardware or software in a different way.



Base on machine platform



Base on WINS



Base on WINC

On a machine platform (MARM, MX86 etc), the base functions as a real and complete operating system. The kernel and device drivers use the machine's hardware. The file server presents the ROM as drive z:, and uses the RAM for drive c: — shared dynamically with other applications' use of RAM. The file server may also use removable media for other drives. A hardware abstraction layer (HAL) is used to allow much of the base to be re-used without change, even for radically different underlying platforms. On machine platforms which share a common instruction set, such as ARM variants, different implementations require only slight alterations to some device drivers and configuration files.

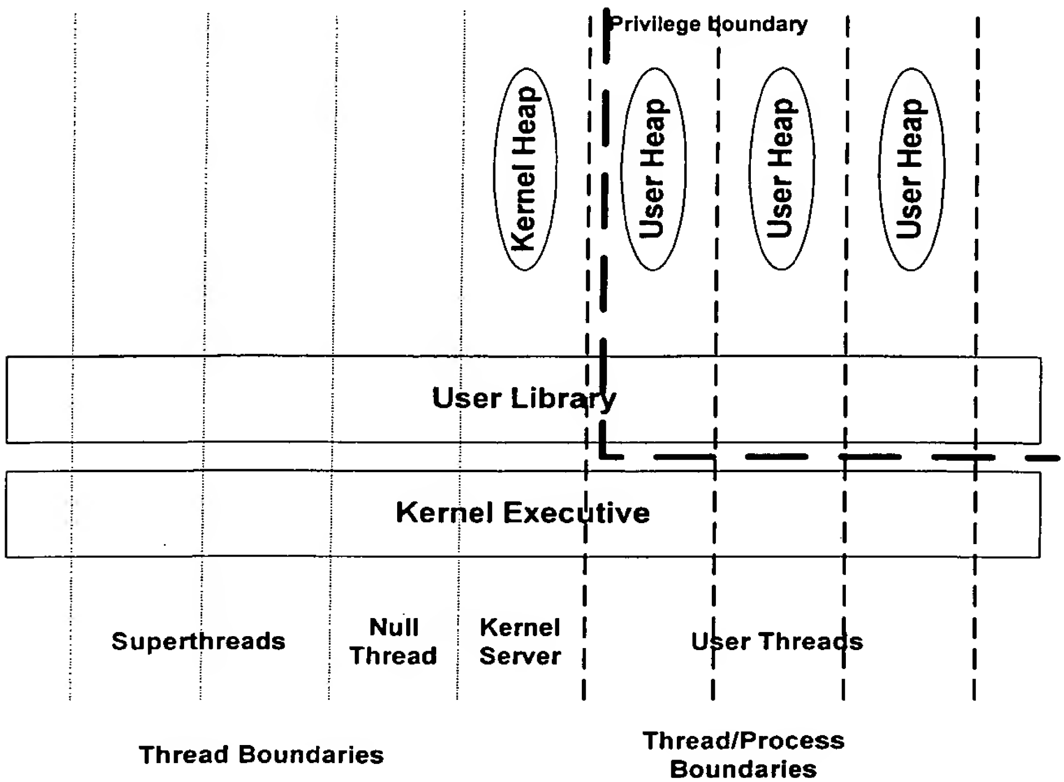
WINS is an emulation of a machine platform. The user library API and the client interface to the file server are essentially identical. User programs built on the WINS base use exactly the same source code and binaries as for MX86, and the same source code as for MARM.

The WINS kernel and device drivers use the Win32 API to provide services. For example, the EPOC32 screen is mapped to a window on the PC screen: the size and background bitmap for the window may be configured to represent a variety of EPOC32 target machines. In all other respects, the emulator window functions just like any other Win32 window. The HAL presents various intended hardware emulations to higher-level parts of the base.

The WINS file server maps drive c: onto \epoc32\wins\c\ on whatever drive the SDK is installed. z: is mapped onto a directory whose name depends on the variant of the WINS platform: for narrow debug builds, z:\ is mapped to \epoc32\release\wins\deb\z\. This means that an EPOC32 program under development, even if it has serious bugs, will not be able to damage the users' PC-based files — or even the installed EPOC32 SDK.

WINC is designed to run the WINS application engine binaries, driving them with format conversion programs that form part of EPOC Connect desktop connectivity software. As under WINS, the user library and file server provide substantially the same API as on a machine platform. As under WINS, the kernel and device drivers use the Win32 API to provide services. Unlike WINS, there is no support for graphics and no need for a screen window. Also, since the driving program is not an EPOC32 user program, but a Windows application, the WINC file server does not attempt to map file references into safe areas: instead, the whole PC file system is available and the driving software is responsible for using it correctly.

2.2.2 Kernel and user threads



EPOC32 system, showing kernel and user threads

As in all multi-tasking systems, EPOC32 user threads run for the most part in unprivileged state. User threads access the kernel via the kernel executive, whose services are presented through the user library API. A user thread can directly access only its own data, plus data belonging to other threads in the same process.

The kernel and executive run in privileged state, and can directly access all parts of the system.

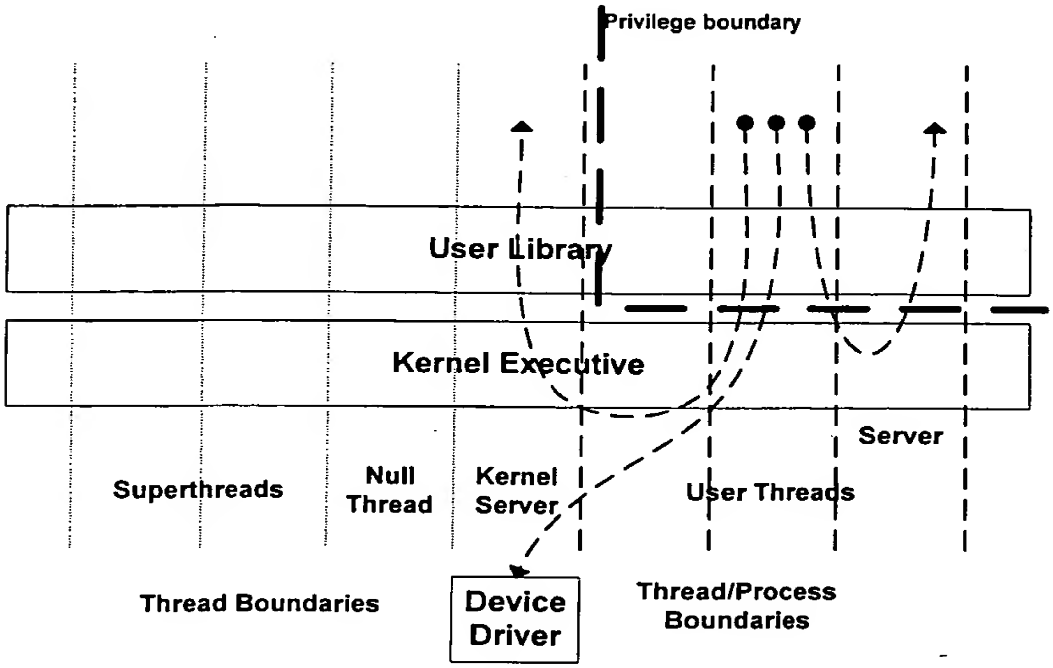
The kernel server thread is always present. It is the highest-priority thread in the system, and performs services on behalf of other threads. The kernel server owns all kernel resources, which reside on the kernel heap. Kernel resources may be used by the executive, operating in the context of any thread, or by other kernel-side threads. However, kernel resources may only be allocated by the kernel server. This design minimizes context switching and locking in the system. It allows the system to run essentially without disabling interrupts, so that interrupt latency is in the order of a few microseconds.

The null thread is always present. It is the lowest-priority thread in the system and therefore only runs when there is nothing else to do. It quiesces the CPU electronics so as to save power, and sets an inactivity timer which will turn off the entire machine if no user activity is initiated within a given time interval.

Interrupts run without any thread context. Interrupt service routines typically store a minimum of context, and then post a thread ready for execution. A critical measure of real-time performance is the maximum possible latency between an interrupt occurring, and its handler thread being scheduled. For normal user threads, this latency is limited by the longest-running kernel server request. For superthreads, which run kernel-side and do not

use the kernel server to allocate resources, a much faster guaranteed thread latency can be achieved.

2.2.3 Requesting services



Requesting services from a user thread

A user thread may use services provided by the kernel, by i/o devices, or from other threads which function as servers.

User threads request kernel services by using the user library API. The services are carried out by the kernel server thread. Such services include extending the heap, timers, semaphores, creating processes and threads — anything fundamental to the operation of the machine.

User threads request services from i/o devices by using an API provided by a user-side device driver library. The device request is handled by a kernel-side device driver. Device drivers include the keyboard, digitizer, screen, sound, RS232, infra-red and others.

User threads request services from servers by using an API provided by the server's client interface library. The service is carried out within the server thread. Servers are used for all high-level services: in EPOC32, this means anything which is not interfacing directly with the kernel or with a device. Servers are often used to manage a single resource on behalf of multiple clients, controlling sharing or exclusive access where necessary.

2.2.3.1 Message passing

Whether kernel, i/o device or server are used to provide a service, the client thread uses a handle object — only one or two machine words — to represent the service provided by an object whose body resides in the provider. Service request functions are translated by the client-side library into a message, which may consist of a request code and up to four machine-word paramaters. The executive sends the message to the service provider. The service provider may respond with a single machine word, which is used as a return value to

the client. For services requiring more parameters, or bulk data transfer, inter-thread Read() and Write() functions are available.

The service provider may represent the object with a potentially complex and large class. Depending on the type of service, objects may be shared so that different client threads may access them, each client using its own handle for the object. The service provider must monitor all its client threads so that, if any of them terminates — whether normally or abnormally — all the server-side resources it currently owns may be released.

2.2.3.2 Client/server model

Many EPOC32 services are provided by server threads, which are used to manage and share a resource on behalf of multiple clients. In turn, these servers often own and drive i/o devices on behalf of their clients. Examples include the file server, responsible for sharing and manipulating all files, file systems, devices and media; the window server, responsible for sharing the screen, keyboard and pointer; and the serial communications server, responsible for implementing serial communications protocols. The client-server framework is so easy to use that, if you need to write a multi-threaded application, it's often easier to structure the dependent threads as servers than to use the thread services raw.

The client/server model is fundamental to EPOC32. Message passing is lightweight. Context switching and inter-thread read/write in the same process is fairly lightweight. Context switching and inter-thread read/write across processes is somewhat more expensive. Servers with critical performance requirements may use several techniques to minimize the more expensive operations. The window server's client API buffers many client requests before sending them to the server for execution *en masse*. The font and bitmap server has a shared heap: the server controls allocations on it, but clients may access it directly to blit to and from it. All EPOC32 communications servers run in the same process, so that inter-protocol requests are handled with no inter-process communication.

2.2.3.3 Asynchronous processing and active objects

Many kernel-, i/o- and server-provided services complete asynchronously. In order to save power, clients use EPOC32 services to wait for completion of asynchronous services, rather than a tight polling loop. As a result, EPOC32 is a heavily asynchronous system. All threads spend most of their time waiting for one of a number of outstanding requests, and then briefly handle requests as they are completed.

This is such a common requirement that EPOC32 provides an *active object* system. This is one of Psion Software's most powerful inventions: its design was pioneered in EPOC16. Most threads use an *active scheduler* which manages one or more active objects. Each active object is responsible for requesting a particular service, and then handling its completion. Handling completion may take from a few tens of instructions, to a couple of seconds: often, handling completion will result in issuing more requests for asynchronous service. Active objects effectively support non-preemptive multi-tasking in the context of a single thread. Non-preemptive multi-tasking is much more efficient, and easier to use, than pre-emptive multi-threading. As a result, it is easy for developers to write applications which maintain responsiveness to their users, and it is very rare for applications or even servers to use more than a single thread.

2.2.4 User Library

The user library presents user-side facilities available to all user threads and, in some cases, to kernel-side services also.

The user library provides the Leave() function, and cleanup facilities which make it easy for programs to detect errors such as out-of-memory, and to clean up partially allocated resources. Strings and fixed-length data buffers are supported by a unified class hierarchy: the descriptor classes. In addition to active objects, EPOC32's cleanup support and descriptors are among its most distinctive aspects.

A conventional group of support functions for DLLs, threads and processes is provided. Data structures include lists, dynamic memory buffers, and extensible arrays which build on these buffers. Good use is made of C++ templates to provide type-safe collection classes. Math functions manipulate IEEE754 double-precision floating-point numbers, and text functions include support akin to sprintf() in standard C, and a lexer akin to sscanf().

2.2.5 File server

The file server manages files on behalf of all client threads in the system, and also on behalf of the kernel.

The file server presents an object oriented API to its clients, through which clients may manipulate drives, volumes, directories and files. The API delivers all POSIX-required services, plus some specific to EPOC32.

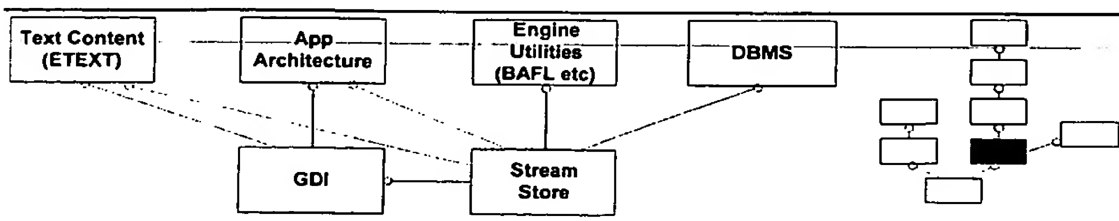
Volumes are formatted using VFAT: filenames, including their drive and path, may be up to 256 characters long. EPOC32 applications do not use file extensions.

On a machine platform, the ROM is mapped to drive z:, and contains an unlimited VFAT directory tree. The RAM is dynamically allocated between user threads and between the c: drive: there is no need for a user to specify how much RAM should be reserved for the file server. Removable media are supported, on CF cards (compact flash, a small form-factor adaptation of the PC card standard). Remote drives, on any other computer connected by a communications link, are supported through installable file systems.

The file server implements the program loader which supports both .exes and DLLs. Both are executed in-place from ROM, and loaded as needed from RAM or from removable or remote drives. On machine platforms, DLLs are restricted to linking by ordinal, rather than by name: this prevents space being wasted by potentially long names. Production of link-by-ordinal DLLs, and maintenance of binary compatible enhancements to them, is fully supported by the EPOC32 tool chain. On machine platforms, DLLs may not have writeable static data: instead, object handles must be passed directly, or thread-local storage (TLS) must be used: there is one machine word of TLS per DLL per thread.

A unique aspect of the EPOC32 file system is the use of 32-bit UIDs (unique IDs), which allow the type of every executable (.exe or DLL) to be identified. This serves as a form of identification, used among other things for associating an application file with its owning application. It also protects against accidental loading of a DLL which is not the version or type required.

2.3 Engine support



Engine support components

The engine support components of EPOC32 build on the base's facilities and provide support both for application engines, and for the graphics components of EPOC32. The engine support components are available under WINS, machine platforms, and WINC. Because the base presents binary compatible APIs on all x86 platforms, engine support component binaries are identical on WINS, MX86 and WINC. For MARM, only recompilation is necessary from the same source code.

2.3.1 Stream store

The stream store is fundamental for engine support. Applications' data is stored in a network of streams, and streams are stored in a store. This store may be a file, or it may be a clipboard, undo buffer, or other implementation. File stores include two types: a direct file store in which streams are written just once and which is suitable for most applications, and a permanent file store in which streams can be manipulated at will, which is suitable as a foundation for a database. All EPOC32 applications use file stores for their main documents. Embedded documents are supported by embedded stores, whose interface is similar to that for a direct file store.

The stream store is used for all data storage requirements in the system, and it is a requirement of any component, or application engine, that it be able to store its data in a stream, or in a store using a network of streams. Therefore, all other engine support components use the stream store.

2.3.2 DBMS

The stream store is also the basis for the database management system (DBMS), which uses a permanent file store to provide a relational database containing an arbitrary number of tables. Commit and revert are supported, together with incremental compaction and space reclamation. An SQL subset is provided to allow views to be constructed on data from a table in the database. The database makes very efficient use of RAM and file space, and can recover from operations that were interrupted — say, by an emergency power-off.

2.3.3 GDI

The GDI implements no graphics, but it is fundamental because it provides the abstract base classes used by all graphics on the system. These include a graphics device, a graphics context (used for all drawing), colour, measurement and zooming support, printer support and fonts.

2.3.4 Text content

The GDI's definitions are used in turn by the text content model. This is a powerful component of EPOC32 which allows rich text to be manipulated with ease. This supports a variety of applications ranging from the word processor (which simply manipulates a single rich text object) to entries in databases, agendas and spreadsheet cells. Text content may also be stored in any stream store.

2.3.5 Application architecture

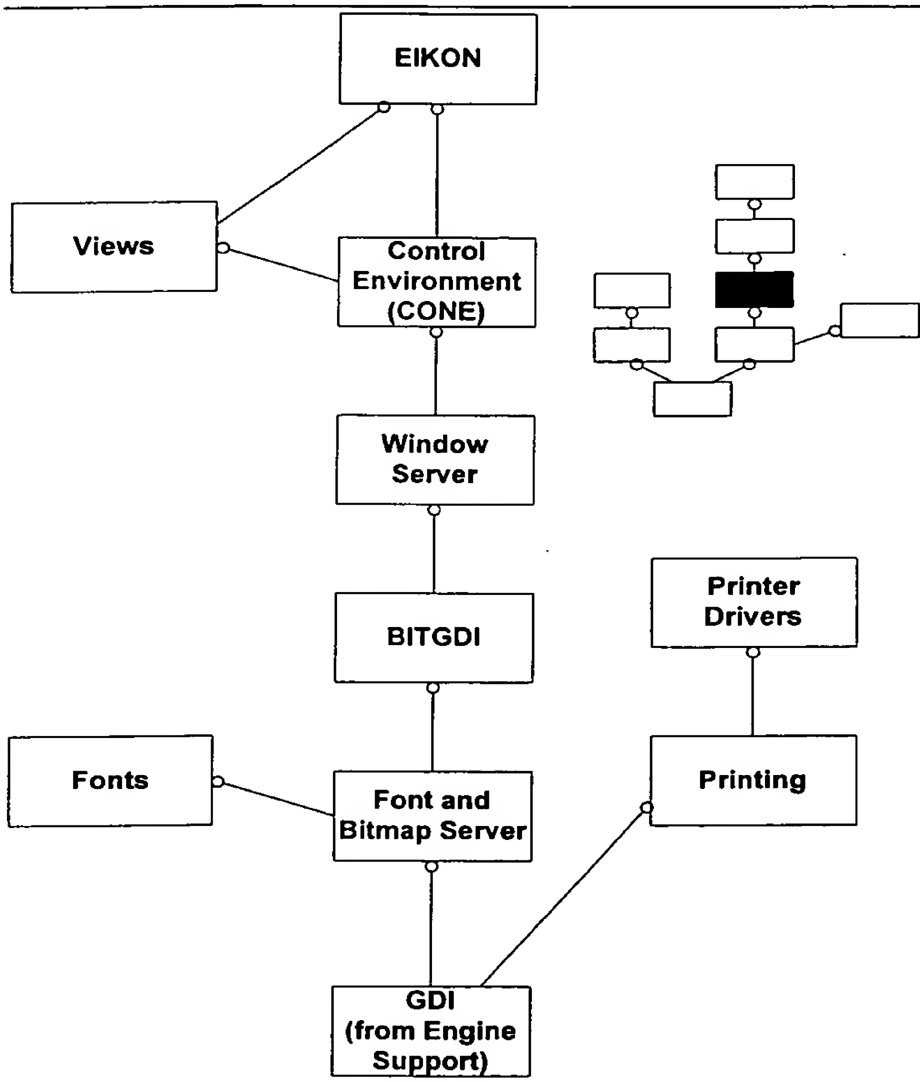
The application architecture specifies all the architectural issues to do with finding applications, tracking running applications, file locations, icons and captions, and object embedding. It provides an extensible system of language environment support: each language environment provides its own plug-in facilities to recognize and run applications. Currently, EIKON, OPL and .exe programs are supported. A future language environment

such as Java could provide its own recognizer and run under the present application architecture without changing it.

2.3.6 Engine utilities

Finally, the engine utilities provide more useful tools, including resource file support (used for specifying GUI components and translatable text strings), clipboard support, sound utilities, specialized array classes, an alarm server, and a world data server.

2.4 Graphics



Main graphics components, between the GDI and EIKON

EPOC32's graphics components fulfil the requirements specified by the GDI, in two main contexts: firstly, the screen device and secondly, printers. Together, the graphics components form the basis for the EIKON GUI.

2.4.1 Central tower

The font and bitmap server and BITGDI provide the low-level data management and rendering needed to produce graphics on screen, or off-screen bitmap. The ARM

processor's RISC instruction set enables the BITGDI to perform as an extremely effective blitter and graphics renderer.

The window server builds on these components, using the BITGDI to draw graphics on the screen, clipping each operation to the boundaries of its window — whether that window is fully visible, or partially hidden by others higher up in the window order. CONE, the control environment, provides the abstract base class used by all GUI controls: a control is a rectangular region which may be either a whole window, or just a part of it. Additionally, any control may contain zero or more component controls.

As well as graphics, the window server drives the keyboard and pen. Keystrokes are sent to the application with focus, and pointer events are sent to the application owning the window in which they occurred. CONE packages these facilities, offering each key event to a stack of controls in turn, and routing each pointer event to the control in which it occurred. Together, CONE provides sufficient framework for both individual controls, and controls in the context of a thread which may be running multiple embedded applications.

These facilities provide a powerful programming framework. However, the central graphics tower imposes no user interface policy: menus, dialogs, toolbars, buttons, window borders etc are all the responsibility of the GUI, which uses the facilities of the graphics component.

2.4.2 Views

Built on the graphics system are several high-level views, all available for applications' use.

Text views provides an interface for displaying, editing and rapidly reformatting text content. This is a complex process. Because it is provided as a system component of EPOC32, it is available for use in any application.

Chart provides business graphics, and is used, for example, by the Sheet application, to provide charts data based on a spreadsheet range.

Grid provides a grid of rich text data. It is the basic component of a spreadsheet, but can also be used for other applications.

Clock provides self-updating digital or analog clocks.

2.4.3 Fonts

The font store supports a variety of ROM fonts and also allows applications to define their own and add them to the font and bitmap server until they are no longer required.

EPOC32 comes with Times New Roman, Arial and Courier New, plus some symbol fonts and special UI fonts, such as LED-type digits for the calculator and similar applications.

2.4.4 Printing

A generic print component provides printer support and several printer drivers for popular printer families.

Each printer driver provides its own font metrics, and turns the GDI commands issued by an application when printing, into the relevant instructions for the target printer. It is possible to use the printer font metrics when formatting for the screen: the text views component does this, to provide genuine WYSIWYG for the word processor and other applications. A print job may have a header and a footer, each optionally hidden on the first page: the header and footer each use rich text, and so support rich content, including fields for the page number and total number of pages. All print settings can be stored in a stream, and therefore contained as part of any application's document content.

A special type of printer driver provides an on-screen preview of any print job. It is therefore easy for all applications to support print preview.

Another printer driver drives a Windows-hosted printer through EPOC Connect. EPOC Connect also allows font metrics of any TrueType font to be downloaded to the EPOC32 machine, so that WYSIWYG formatting on the EPOC32 machine is still possible.

A final special case is fax. Any application that can print may be also be faxed.

2.5 Comms

EPOC32's communications support revolves around two servers: the serial communications server (comms server) and the sockets server.

2.5.1 Serial communications

The comms server provides a client API and several serial protocol implementations, each of which is written to a provider interface. Clients may be in any thread, but all serial protocols run inside the comms server thread.

The simplest comms protocol drives the built-in RS232 device. Because of the history of serial communications, and the subtle differences in devices, the entire hardware interface to the device is exposed, and the comms server's client API mirrors much of this complexity. Other protocols include IrCOMM and telnet. The comms server easily attains 115kbps on an 18MHz ARM 7100.

Despite the complexity of the entire API, the central portions are relatively simple to use and, once a session has been set up, they are entirely device independent.

On the client side, XMODEM and YMODEM are supported.

2.5.2 Sockets and networking

The socket server's client API provides a object-oriented version of the BSD-compliant sockets interface, to clients which may be running in any thread. The provider interface provides, in layered form, support for any sockets protocol. Implementations include TCP/IP, IrDA, and Psion Link Protocol (PLP).

The TCP/IP implementation supports a rich variety of protocols, including SLIP and PPP.

PLP is a proprietary protocol, used for compatibility with EPOC16, and for communication to the PC using EPOC Connect.

2.5.3 Dial-up and scripting

Dial-up connections are supported by a telephone dialler, using a dial engine which performs transformations on telephone numbers to dial the correct tone sequence. The same engine can be used for DTMF dialling for voice connections. A scripting engine supports the potentially complex process of signing on to a dial-up service.

2.5.4 Port sharing

The flexibility of the comms systems is enhanced by device support which allows each comms device to be opened and used by more than one thread, provided that when a read or write to a port is outstanding from one thread, no other thread tries to initiate a new read or write.

One application of this flexibility is that the serial port may be driven by one thread to establish a connection to a dial-in service using the script engine, and then handed over to the comms server once a connection is made.

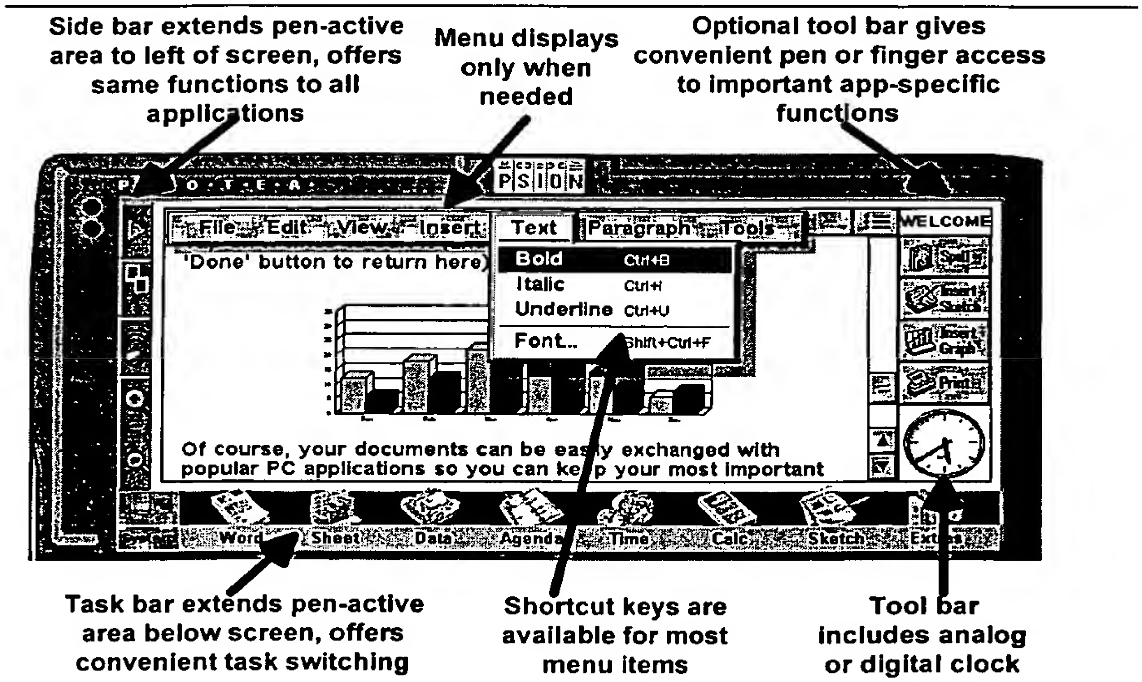
3. EIKON

EIKON is the default GUI for EPOC32. It builds on the central tower defined by the base, engine utilities and graphics components. It also uses other machine facilities, notably comms.

EIKON has been designed specifically for the requirements of handheld machines. It provides the look and feel for users, a framework for programmers, and an environment for applications.

In some circumstances, an EPOC32 machine may use a different GUI instead of EIKON.

3.1 Look and feel



EIKON screenshot and main elements (on Psion Series 5 WINS emulator)

From a user's point of view, EIKON defines the look and feel of an EPOC32 machine. It has been designed to make this as attractive as possible. Above, EIKON is shown running the Word application on a Psion Series 5, under the WINS emulator.

EIKON is easy and pleasant to use, both for novices, and for experienced users. It uses real-world metaphors for some things but, as PCs are now part of the real world, PC metaphors such as menus, dialogs and toolbars are also used. These can be quickly learnt, and the experience of other platforms has demonstrated that complete departure from PC to other "real-world" metaphors, while it can be fun for a few minutes, severely compromises the overall usability of the machine.

Instead of abandoning the PC metaphors, EIKON has made them easy to use. Considerable attention has been given to the wording and layout of text in menus, dialogs

and error messages. Dialogs are navigated using arrow keys rather than TAB. Cues are given when keyboard shortcuts are available — except for pervasive, standard, keys, such as ESCAPE and ENTER.

The i/o devices of a handheld are different from those of a PC: EIKON has been designed to make EPOC32 machines pleasant to use with both the keyboard and a pen, and has been designed to use the available screen optimally.

3.1.1 Pleasant with keyboard

Although it is one of EPOC32's key features that it supports pen-based devices, keyboard operation is still critically important. A good quality keyboard is still the fastest and most accurate way to enter large amounts of text. In some conditions, the environment may not allow pens to be used with great accuracy.

EIKON provides powerful dialog facilities, but dialogs are navigated using the arrow keys rather than tab. Left and right arrow keys are often used to navigate within controls, but up and down navigate between controls on a single dialog. This provides obvious behaviour to users, and makes it natural to use dialogs with the keyboard. As a consequence, dialogs provide only a one-dimensional — vertical — array of controls. In practice, this is not an onerous constraint. Multi-page dialogs provide a natural interface, especially for rich features such as print setup or agenda entry settings. Custom controls may be written — containing existing controls if necessary — which provide horizontal navigation for some dialog lines. The one-dimensional control list may be extended by using a scolling dialog.

The most common application commands — such as Edit | Copy — are available from both menu and keyboard. Some keyboard shortcuts are defined in the EIKON Style Guide (Edit | Copy is CTRL+C, for instance, which is familiar to users of Microsoft Windows applications). Some keyboard shortcuts are application-specific.

Menu items, and buttons in dialogs, which have keyboard shortcuts associated with them, are indicated by an appropriate label. EIKON provides this support automatically, without programmer intervention.

3.1.2 Pleasant with pen

EIKON has also been optimized for pen usage. Because a pen is not a mouse, different gestures are appropriate. Pens are good for freehand drawing, but bad for accurate double-clicks and for drag-and-drop. Clearly, a pen cannot do a right-click. EIKON keeps the pen interface simple by supporting only the simplest operations with the pen.

The double-click operation familiar to mouse users is replaced in EPOC32 by select and open. A pen tap on an unselected object will select it. A pen tap on a selected object will open it. The time interval between selecting and opening is irrelevant.

EIKON makes further use of the pen by presenting an application-specific toolbar to the right of an application's window: the toolbar provides commonly used functions at the press of a button, and also a clock.

EPOC32 allows the digitizer to be extended beyond the visible area of the screen. EIKON uses this to provide a pen-activated side bar on the left with menu, clipboard, infrared and zooming functions. The digitizer may also be extended below the visible area of the screen, to provide a task bar with application-switching functions.

Standard controls and views provide many active elements. For instance, clocks in the toolbar may be changed from analog to digital by tapping them. The time may be set from

the Time application by tapping on the clock. Dog-ears are available on the Agenda views to turn pages.

The majority of pen-enabled UI elements are sufficiently large to select comfortably with a pen, even under unfavourable conditions. Buttons on screen, side bar and task bar may even be selected with a finger.

3.1.3 Pleasant with screen

Today's standard desktop PCs have high-contrast colour screens, centred around a 1024x768 display form factor. Modern GUIs are designed to take advantage of these capabilities to present a pleasing interface. However, handhelds' displays are less capable than this. They centre around smaller screen sizes, greyscale or more restricted colour capabilities, and sometimes lower contrast. Handhelds are also used in a wide variety of lighting conditions ranging from outdoors, through brighly lit offices, to subtly lit rooms at home or even the bedroom at night!

EIKON makes good use of screen space by displaying menus only when needed, and allowing the toolbar to be optionally turned off. Since the task bar is off-screen, there is no need to permanently waste screen space displaying the applications currently running. Cascaded menus allow the length of menu panes to be shortened to fit within a shallow screen depth. Multi-page dialogs, besides being a valuable GUI paradigm in their own right, also help to conserve space.

To support displays with lower contrast, EIKON makes use of strong contrasts for its user interface elements. Available options are displayed in black on white, in a reasonable-sized font.

Finally, almost all application views support zooming to three, four or five magnification states. This allows the zoom state to be tailored to the best compromise between amount of information displayed, and visibility, depending on lighting conditions, the application's data, and the user's eyesight. Since easy adjustment is a critical comfort factor, zooming is a side-bar function, always instantly available.

3.2 Rich GUI elements

EIKON provides a rich set of GUI elements. Users can send commands to applications using menus, shortcut keys, or toolbar buttons. Menus support cascades. Dialog support includes single and multi-page dialogs and even scrolling dialogs for special applications.

Many standard controls are available, including number and text editors, list boxes and combo boxes, font and sound selectors, and controls optimized for personal information management, such as convenient time/date navigation, and latitude and longitude editors.

Scroll bars have dynamically-sized grab handles, and scroll application data automatically.

Many types of list are supported, including hierarchical lists, multi-column lists in which each entry has several aligned fields, and snaking lists which wrap vertically into a container. A variety of standard lists is provided, and owner-draw lists may be written.

A console is available for displaying comms terminals and text-based shells, like an MS-DOS prompt under Windows 95.

Standard higher-level components include file browsers, Open and Save As dialogs, print settings and print preview.

These standard components, plus the flexibility for programmers to define their own controls, make EIKON the most powerful GUI available for handheld use.

3.3 Framework for programmers

EIKON provides a powerful framework for programmers. To a first approximation, any application program may be thought of as an engine plus a GUI. GUI programming in turn divides into issuing and handling commands, drawing application views, and handling commands with dialogs.

In EPOC32, separate engine development is encouraged. A well-structured application's engine will be completely independent of EIKON.

Commands may be issued using either menus, toolbar or shortcut keys. It is easy to specify any of these methods, using a resource file. An EIKON application provides a single function to handle all commands: typically, this identifies the command and invokes another function to process it.

Application views consist of one or more controls, which allow the application to draw its data, and to handle interaction through keyboard and pointer. Usually, the application re-uses the same drawing code for the control used in the view, for printing, and for drawing as a glass door.

Many commands are handled using a dialog to specify some further parameters, before doing some action. Dialogs are specified in a resource file and implemented by deriving from EIKON's abstract dialog base class. Facilities are provided to get data into and out of dialogs, validate controls individually, and ensure consistency across controls. In addition to the wide range of controls provided by EIKON, you may include custom controls in a dialog. Dialogs are automatically laid out when they are constructed, so that it is not necessary to specify pixel positions and sizes in the application. An additional benefit of automatic layout is that dialogs adjust automatically, when the application is localized into new languages.

3.4 Environment for applications

EIKON provides a rich variety of facilities for applications, including packaging many underlying system facilities in an easy-to-use way.

Under WINS, in debug builds, EIKON defines a set of debug keys which may be used to test application redraw logic and resource usage.

3.5 Replacing EIKON

EIKON is a GUI defined for a certain class of machines. For machines significantly outside this class, EIKON may be less appropriate. In the EPOC32 architecture, EIKON is a component that may be modified or even replaced altogether.

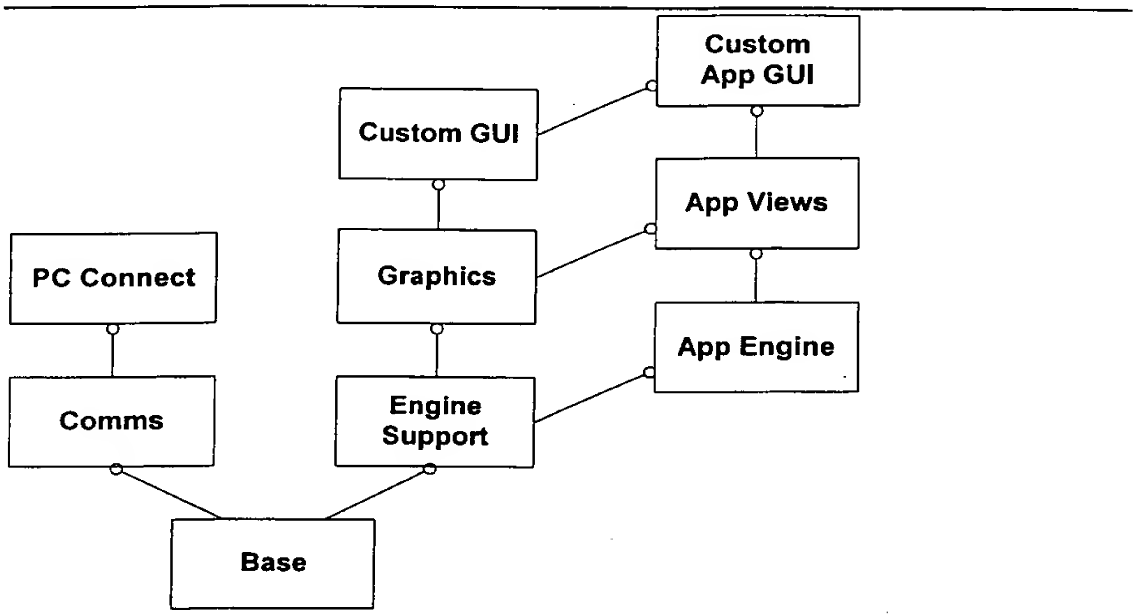
To understand this, compare EIKON with Windows 95. Windows 95 is designed for machines whose design point centres on a high-resolution, high-contrast colour screen, and a mouse with double-click and right-click. It is suitable for machines like that, but works less well on handhelds.

On the other hand, EIKON is designed for handhelds with a medium-resolution, lower-contrast LCD, a keyboard and a pen. This is the centre-point of the handheld computer industry and will remain a profitable sector for developers and applications. The market for this type of device is expected to grow from about 1.5m units in 1996 to over 6m in 2000.

However, it is not the whole industry, and EPOC32 as a whole is capable of supporting a much wider range of devices — both smaller and larger. For machines with smaller form factors, or no keyboard, EIKON may be heavily customized or replaced by an altogether

different GUI. As an indication of the size of this type of market, forecasts for digital mobile phone sales in the year 2000 centre around the 400m mark.

EIKON may also be replaced for commercial reasons. One way to avoid over-commoditizing the mobile computer market is by product differentiation based, for example, on different GUIs. Although the costs and benefits of such an approach must be weighed carefully, EPOC32 does make this approach possible.



Custom GUI: gain maximum application-level re-use through app views

Although it will remain profitable to develop for the EIKON API as-is, some developers may wish to provide applications which allow them more flexibility to port to modified EIKONs, or replacement GUIs. The best way to do this is to write significant parts of an application's views independently of EIKON. As with application engines, this approach supports the modularity of EPOC32, and there are also independent benefits. One reason is because substantially the same view code should be used for printing. Another is that, if the application supports embedding using glass doors, the view can be re-used again to draw a glass door.

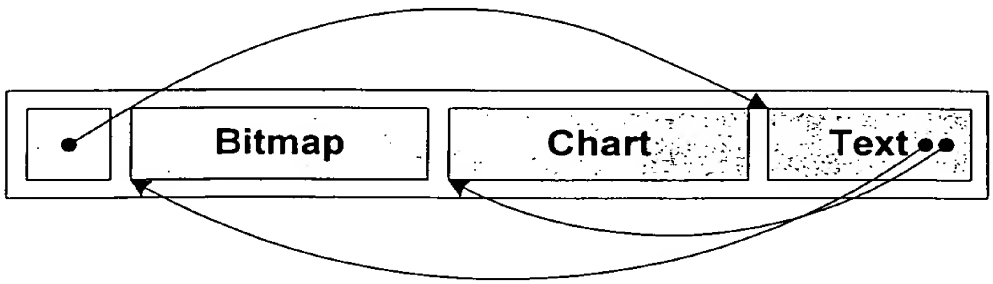
4. Object Orientation and Re-use

One of the theoretical benefits of object orientation is re-use. This is important to EPOC32, for two reasons. Firstly, because the ROM is much smaller than a modern PC's hard disk, re-use is vital if a wide range of powerful applications is to be delivered to the owner of a handheld computer. Secondly, time-to-market pressures on developers can only be met if developers are able to use a substantial body of existing libraries, rather than [re-]invent their own. Therefore, although re-use remains a theory in many contexts, EPOC32 achieves it in practice. This re-use is pervasive: applications, although powerful, are relatively thin compared to today's PC equivalents. The system itself exhibits much re-use, and is therefore able to deliver enormous power in a compact package.

At low level, EPOC32's re-use begins with its user library, which is a conventional collection of utility classes. At higher levels, re-use of components makes for much of EPOC32's power. Some of the more interesting components are described below.

4.1 Stream store

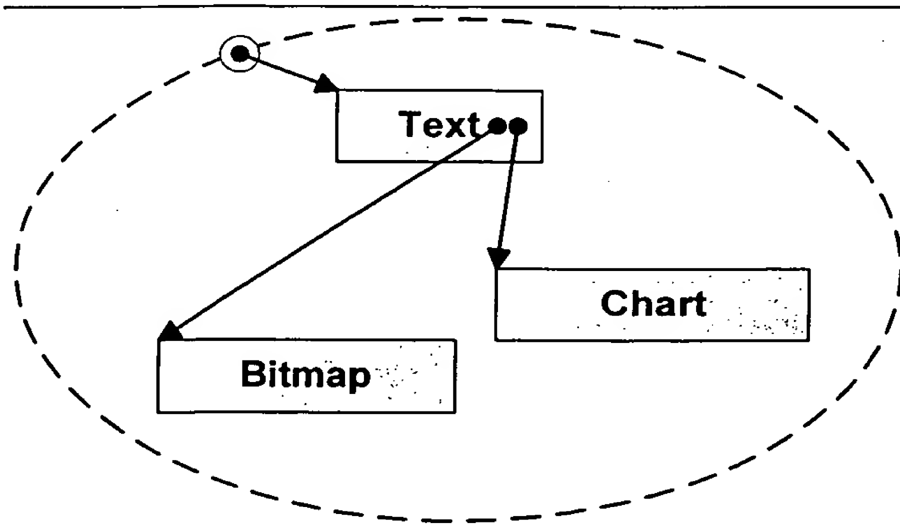
In a conventional system, data is stored in files. For instance, a word processor document containing an embedded bitmap and an embedded chart may be stored in a file containing three segments as follows:



Word processor document with two embedded objects, in a file

For conventional direct access to the file, the word processor would save all the data sequentially, starting with the embedded objects, and ending with the text stream itself. References within the file would use seek positions, and would all be backward — useful, because by the time they are needed, they are already known. The seek position for the top-level text stream would be stored in a reserved location at the beginning of the file: this is also possible, if you reserve a fixed amount of space (say, four bytes) at the head of the file before writing the other data. A file format like this is relatively easy to produce. It is efficient, and has an important advantage: the embedded objects do not have to be loaded along with the main text stream, until it is needed.

A stream store may be thought of an an abstraction of such a file. We represent it like this:



Word processor document with two embedded objects, in a stream store

Each stream in the store is identified by a stream id. The whole store has a single root stream. One stream may refer to another using its stream id.

The store interface is abstract, but has a number of concrete implementations. One, the *direct file store*, provides exactly the function required by the word processor above: the streams are written in sequence, the stream id is represented by a seek position, and the root stream is stored in the file store's header. The direct file store is used by most

applications with load/save behaviour — such as a word processor. When the application saves its data, the old file store is replaced entirely (usually, for safety, it is renamed until the new file store has been written successfully).

Another concrete store implementation is the *permanent file store*. This uses a much more complex implementation, allowing streams to be manipulated — added, deleted, extended, re-written etc — at will. The implementation has taken great care to ensure that updates are atomic, even under failure conditions. As a result of these complexities, stream ids bear no relation to seek position — in fact, in general, you should make no such assumptions about stream ids. Such stores are suitable for database type applications, in which entries are loaded, manipulated and saved a few at a time. It is called a permanent file store because, although entries may be replaced when they are saved, the file store itself is not replaced.

Other store types are used to implement the system clipboard, in-memory buffers used sometimes for undo processing, buffers used for communications (eg, infra-red beaming of application data), and system ini files.

Most classes in EPOC32 are either stream-aware (they can externalize to and internalize from streams), or store-aware (they can store to and restore from stores, creating and manipulating streams as necessary). Because of this, and because there are so many types of store, the system is very flexible and promotes re-use in many ways. Provider interfaces allow new types of stream and store to be written, which further extends the possibilities for re-use.

4.2 Printing

The GDI defines a conventional banded printing model. Because all graphics devices support zooming and scaling, a print device is not fundamentally different from any other type of device. An application's view code can therefore be re-used to draw to a banded printer.

EIKON provides a set of re-usable printing components, available to any application. Print preview uses a print device which maps to a window on the screen. A print settings dialog specifies which pages to print, and print setup specifies paper size and margins, headings and footings. Print settings are stream-aware, and so may be stored along with an application's other data in the application's stream store.

EPOC32 provides many printer drivers to drive printers directly, over a serial link or, for maximum convenience, using infrared. If you already have a printer connected to a PC, EPOC Connect provides the facilities to re-use any printer driver written for Windows, and any TrueType font, for printing from your PC.

4.3 Rich text

All operating systems and class libraries provide some support for strings. Real text, however, is much more than strings. EPOC32's text content and views provide a rich text model which is used by most EPOC32 applications.

A rich text object consists of characters, paragraphs and pictures. A wide range of character and paragraph formatting options is available, far more than on any other handheld operating system. Any picture derived from the GDI-provided abstract base class may be included in rich text.

Text content may be stored in a stream store, and may therefore form part of any application's data model. An EPOC32 application such as the word processor has a data model which is simply a rich text object, plus some UI settings such as the cursor location

and zoom state. An application such as the spreadsheet may use several hundred rich text objects to represent its cell data.

Rich text provides a full range of functions to support inserting, deleting and formatting text content. An application which manipulates text interactively should coordinate its text content updates with calls to the text views formatting engine, which maintains a display on the screen. The text views API has been designed for convenience in use, and enables editors to be written which manipulate large documents with no noticeable performance degradation when compared with small ones.

EIKON provides standard editors for rich text, available either stand-alone or as components of dialogs, for re-use by any application which manipulates rich text.

Re-usable rich text is a technology that Psion Software pioneered in EPOC16. It is a difficult technology. In conventional systems, application authors who wish to present a non-trivial interface to their users often end up with one of two undesirable situations: either they do not attempt the task at all, or they achieve only a minimal and quirky implementation — and pay a relatively high price even for that. EPOC32's facilities are ready for re-use, and allow developers to present a consistent, efficient and usable interface to applications.

From a technology point of view, rich text also presents another convenient aspect of re-use: the text views does not use the text content model directly, but through a carefully defined interface. This interface may be provided by another content model, such as a web browser or large-scale text browsing application. This allows the application to provide the text content in an application-optimized way (perhaps implementing dynamic decompression from a read-only database), but to re-use the layout and formatting capabilities of text views for display and printing.

4.4 Object embedding

In EPOC16, Psion Software's Agenda application had a very convenient facility to attach a memo to an item, so that an item such as "Planning Meeting" could be written, and notes could be added to prepare for the meeting, to take notes during it, etc. The memo facility invoked the word processor in an ad hoc way.

In EPOC32, a graphical user interface gave rise to many more possibilities for embedding. For instance, you might wish to embed any kind of picture in a word processor document, or a signature bitmap in an Agenda, or a voice memo in a word processor document in a database. A general-purpose embedding system was needed, to allow potentially any application's data to be embedded in any other's. The object embedding architecture consists of several parts, specifying the requirements for data, user interface, and application behaviour.

4.4.1 Data requirement

The data requirement for embedding is met by stream stores. Application data "files" are referred to as *documents*, and are stored in stream stores. The environment constructs the stream store, and the application uses it without knowing what type of store it is.

For a main document, the environment may construct either a direct file store or a permanent file store, depending on the requirements of the application.

For an embedded document, the environment constructs another type of store, the *embedded store*. The embedded store uses, as its underlying medium, a stream in the containing store. An embedded store supports the same kind of operations as a direct file store — therefore, any application whose main document uses a direct file store may also be embedded.

The advantage of using an embedded store is that, if the embedding document uses a permanent file store and wants to delete an embedded document, it needs only to delete a stream. Or, if it wants to copy an embedded document, it needs only to copy the stream data. Compared to opening the embedded document during these operations, this saves RAM, saves having to specify passwords on encrypted embedded documents, and allows deletion and copying of embedded documents even if their associated application is not available.

4.4.2 User interface requirement

Embedded documents must present some kind of user interface, to show a user that an embedded document is available in an embedding document. This interface is referred to as a *door*. If you open a door, you move into the embedded document. Some embedded documents may only be represented by an *iconic* door, which shows an icon associated with the embedded application — this is suitable, for instance, for voice memos, or for long word processor documents. Some embedded documents are represented by a *glass* door: you can see what is behind a glass door without opening it. A glass door presents a picture of the application's data.

4.4.3 Application architecture requirement

The application architecture specifies the methods by which embeddable applications can be found when you wish to embed something in a containing document, and the methods by which the embedding application can be found again when a glass door is drawn, or when a door is opened. It also provides the means to manage an application thread which may have loaded several applications, representing the main document, any glass doors that are being displayed, and any embedded documents that are open. For this reason, applications are all DLLs which run in an existing thread, rather than .exe programs which would each require a separate process.

4.4.4 Embedding for application developers

Object embedding works by re-using several existing components of EPOC32. In turn, applications re-use parts of EPOC32, and parts of their existing code, to support embedding.

The embedding system is extensible, with no fixed set of embeddable applications. To make your own application embeddable, you need to create a door for it. An iconic door is very simple to add. A glass door is slightly more work: most glass-door code benefits from re-use of application view code which has already been written to support on-screen display and printing.

You also support embedding from your own application: re-use rich text as a component of your application, and EIKON's rich text editors will handle the embedding of any application's data.

The power that this system delivers to users can be seen by using an EPOC32 machine's built-in applications.

4.5 Consequences of re-use

The components described above provide particularly powerful re-use which may be appreciated by all developers and users of an EPOC32 system, and which help to make EPOC32 significantly more powerful than any of its competitors.

More conventional components are also available for re-use, ranging from collection classes for arrays and lists, in the user library, to hierarchical list boxes and other GUI elements in EIKON.

For developers, this presents enormous benefit. An EPOC32 developer should assume that a component is available to do a certain task, and spend some time looking for it. At first, this may take a while. However, within a short time, this leads to enormously productive programming, and applications which deliver power to users, in a compact package.

5. Software Development

Psion Software supports EPOC32 software development through its EPOC World organization. EPOC World makes two development options available, each with its own software development kit (SDK).

5.1 +

C++ is EPOC32's native language. The C++ application software development kit includes all user-side class libraries, the WINS emulation in several configurations, tools for project control, resource file compilation, bitmap and sound manipulation etc, plus documentation and example code. Object orientation results in tightly interwoven class relationships; in turn, the documentation needs to be tightly interwoven also. The documentation is delivered in HTML, and includes many navigational aids including links to class definitions from all their references.

To use the C++ SDK, you need a high-spec PC running Windows NT or Windows 95. A 133MHz Pentium, 24MB RAM and 300MB of free disk space are the recommended minimum configuration. You need Microsoft Visual C++ in order to compile for WINS: the SDK itself includes the GNU tool chain required to compile for MARM.

Since WINS uses no MFC libraries, and delivery of optimized executables is not an important issue, the standard or learning editions of Microsoft Visual C++ may be used, thus cutting costs for developers who do not already have a C++ compiler (the recommended price for these variants of Microsoft Visual C++ is $99).

5.2 OPL

OPL is a BASIC-like language that was developed by Psion in the mid 1980s for programming its Organiser range of handheld computers. On these machines, OPL was the only alternative to assembler language.

OPL is also available for EPOC16. OPL allowed rapid application development, and even programming directly on a Series 3 without using another PC. This ease of use, and universality, fostered a large market in personal, professional and industrial applications written in OPL.

The same facility is available in EPOC32. OPL programs written for EPOC16 need only slight modification to run under EPOC32. The OPL language gives access to many EPOC32 facilities. Any facility available to a C++ program may be made available to an OPL program through an appropriate OPL extension, or OPX. Since OPXs are written in C++, the C++ SDK is needed to develop OPXs. An OPL programmer does not need the C++ SDK in order to use OPXs.

The OPL SDK supports more comfortable development of OPL programs on a PC. It includes the WINS emulation, plus documentation, tools and examples not found on EPOC32 machines.

The OPL SDK may be used on a much lower-spec PC than the C++ SDK, under Windows 95, Windows NT 3.51 or Windows NT 4.0. No C++ compiler is needed.

5.3 Other languages

Psion Software has announced a partnership with JavaSoft, and will be releasing a Java compiler.

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